



How the reverse supply chain impacts the financial performance of original equipment manufacturers

Larsen, Samuel

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How the reverse supply chain impacts the financial performance of original equipment manufacturers

Samuel Brüning Larsen

PhD Thesis
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DTU Management Engineering
Department of Management Engineering
Technical University of Denmark

PREFACE AND ACKNOWLEDGEMENTS

This PhD-project is conducted at the Department of Management Engineering at the Technical University of Denmark (DTU). DTU has funded the project as part of an effort to qualify lecturers employed at DTU's centre for bachelor of engineering students (DTU Diplom) to conduct research. The thesis consists of two components: 1) nine papers and 2) a summary of these nine papers. The present document constitutes the latter. Table 1 presents the nine papers, which are all placed as appendices to this summary.

Table 1 – The nine papers of the thesis

P-1	Revenue in reverse? An examination of reverse supply chain enabled revenue streams	J*
P-2	How the reverse supply chain impacts the firm's financial performance: A manufacturer's perspective	J
P-3	How the reverse supply chain contributes to the firm's competitive strategy – a strategic alignment perspective	J
P-4	How the reverse supply chain enables original equipment manufacturers to compete on low price	C
P-5	The profit potential in reverse supply chain functions for catalyst manufacturers	C
P-6	When reverse supply chains make financial sense – The decisive factors for reverse supply chain profitability	J
P-7	Profits in reverse? An examination of the decisive factors for reverse supply chain profitability	C
P-8	Determining the total cost of reverse supply chain operations for original equipment manufacturers	C
P-9	The profitability drivers in packaging materials reuse for manufacturers in business to business environments	C

*J: Journal, C: Conference

Of the nine research papers four are written for journal publication and the remaining five papers are published in scholarly conference proceedings between 2013 and 2016. This summary will refer to the nine papers as P-1, P-2, P-3, etc. Of the four papers written for journal publication, one paper (P-1) is published in the *International Journal of Physical Distribution and Logistics Management* (volume 46, issue 8, 2016), while the remaining three papers (per January 2017) are in the review process with the journals *Operations Management Research*, *Production Planning and Control*, and a special issue of the *International Journal of Physical Distribution and Logistics Management*.

The research disseminated in this thesis is primarily conducted as case study research. During the four-year period from February 2013 to January 2017, the author conducted the research that led to the dissertation's papers. The re-

search was conducted in cooperation with nine manufacturers operating in a wide variety of industries ranging from heavy machinery to miniaturized electronics. As part of the research process the author has conducted two major rounds of data collection followed by several minor data collection rounds. The set of nine papers does therefore not reflect nine separate rounds of data collection. For the development of one paper (P-5), the author did not collect data, but functioned as supervisor of a student project. The author did, however, write and present the paper at a conference (P&OM World Conference, 2016).

I would like to extend my gratitude to my wife and kids, and to my colleagues at DTU, in particular my supervisor Peter Jacobsen, fellow PhD students, and colleagues at DTU Diplom.

SUMMARY

This thesis examines the financial impact of a firm's reverse supply chain (RSC). Specifically, the thesis examines the two questions of how the RSC can contribute to the financial performance of the firm and which factors are decisive for the RSC's financial contribution. The thesis focuses on original equipment manufacturers. The thesis results show that the RSC can contribute to the financial performance of the firm in more than 20 different ways, which the thesis defines as functions of the RSC. Examples of RSC-functions are 1) resale of recovered end-products to price-focused market segments in the firm's primary markets, 2) resale to customers in new markets (in e.g. emerging economies), and 3) sale of used materials back the firm's original material suppliers. The firm' RSC can conduct several RSC-functions simultaneously and the financial benefits from operating these RSC-functions differ widely among functions. The factors that are decisive for the RSC's financial contribution depend on the type of RSC-function. For a RSC-function that recovers and resells end-products examples of factors decisive the function's financial contribution are 1) the market's willingness to pay for recovered products, 2) the firm's profits from servicing recovered products once sold, and 3) the added probability of selling additional products to customers of recovered products. The thesis demonstrates that manufacturers can achieve considerable financial contributions from the RSC, which contracts the traditional perception of the RSC in academic literature as well as with logistics practitioners.

DANSK SAMMENFATNING

Producenter af produkter med en længerevarende levetid (fx måleudstyr, produktionsmaskiner, vandpumper og høreapparater) indgår i en fremadrettet forsyningskæde bestående af leverandører, producenter, distributører og slutbrugere. Igennem denne forsyningskæde bevæger materialer, komponenter og produkter sig. Mange producenter har også et returflow af varer. I returflow'et indgår fx defekte produkter, produkter med afsluttet livscyklus og produkter, som kunder leverer tilbage efter en afsluttet leasingaftale. Det er virksomhedens "bagudrettede" forsyningskæde, der håndterer dette returflow. Denne bagudrettede forsyningskæde kaldes i dansk kontekst for virksomhedens returlogistik.

Denne ph.d.-afhandling undersøger hvordan virksomhedens returlogistik kan bidrage til virksomhedens profit samt hvilke faktorer, der er afgørende for størrelsen af returlogistikens bidrag (forudsat at returlogistikken i det hele taget kan bidrage positivt). I hovedparten af den akademiske litteratur opfattes returlogistik som en omkostningstung byrde, som virksomheden bør minimere. I midten af 00'erne fremkom imidlertid en ny litteraturstrøm, der bryder med denne traditionelle returlogistik-opfattelse og i stedet anskuer returlogistikken som en potentiel værdiskaber for virksomheden. Denne anskuelse danner det teoretiske grundlag i denne ph.d.-afhandling.

En virksomheds profit udgøres grundlæggende af forskellen på virksomhedens omsætning og omkostninger. Afhandlingens resultater viser at returlogistikken både kan øge virksomhedens omsætning og reducere virksomhedens omkostninger. Hvis værdien af dette (dvs. profitten fra den forøgede omsætning eller summen af reducerede omkostninger) overstiger returlogistikkenes egne omkostninger, så bidrager returlogistikken positivt til virksomhedens profit. Returlogistikken kan øge virksomhedens omsætning gennem gensalg (fx af renoverede produkter og komponenter) og gennem øget salg af virksomhedens nye produkter (fx ved at inkludere returlogistik-services i den samlede produkt-pakke, som en kunde køber). Returlogistikken kan reducere omkostninger fx ved at erstatte ny-producerede komponenter med renoverede komponenter (fx til brug som reservedele).

Afhandlingen viser at størrelsen på returlogistikkenes bidrag til virksomhedens profit afhænger af en række faktorer, der knytter sig til sammensætningen af virksomhedens marked, adfærden hos kunderne (som udgør både leverandørerne af brugte produkter til returkæden og aftagerne af renoverede produkter) samt en særlig række karaktertræk ved virksomhedens produkter og tilknyttede services. Blandt de faktorer afhandlingen har identificeret gennem enten egne undersøgelser eller studier af eksisterende litteratur er 1) andelen af "grønne"

kunder i markedet, 2) omkostningen ved at anskaffe brugte produkter, 3) renoverbarheden af brugte produkter, 4) profit-marginen på den service, der knytter sig til et gensolgt produkts brug, og 5) forøgelsen af sandsynligheden for salg af nye produkter til en kunde, der har købt et renoveret produkt.

Ph.d.-afhandlingen viser at returlogistikens værdi for virksomheden ikke blot består af den direkte profit returlogistikens egne processer realiserer (fx gennem gensalg af renoverede produkter), men også af afledt profit realiseret i andre af virksomhedens funktioner. Således bidrager denne afhandling til generelle forståelse af den værdi returlogistikken kan levere til producent-virksomheder. Praktikere kan anvende afhandlingens resultater som støtte til beslutninger om returlogistik-implementering og bedre indsigt i returlogistikens lønsomhed.

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1 INTRODUCTION

The traditional forward supply chain manufactures materials, components, and end-products. End-products are used or consumed by consumers. In addition to the forward flow of products, most firms have *reverse* flows of products that are either returned by customers or actively taken back by the firm itself, often for the purpose of reuse or resale. The set of processes that handle these reverse flows constitute the firm's reverse supply chain (RSC), which is the core concept of this thesis.

Over the past two decades, the industrial use of RSCs as well as academic interest in the topic has increased (Rubio *et al.*, 2008; Sasikumar and Kannan, 2008a, 2008b and 2009; Ilgin and Surendra, 2010). There are several reasons for this development: increasing raw material prices makes reuse attractive because reuse replaces purchase of virgin materials; "green" consumer segments are willing to pay premiums for sustainability, which increases when reuse replaces the use of virgin materials; RSCs can contribute to competitive advantages, for example by enabling liberal return policies; and in some industries regulations force firms to comply with extended producer responsibilities that include materials recycling (Klausner and Hendrickson, 2000; Rogers and Tiben-Lembke, 2001; Stock *et al.*, 2002; Ginsberg and Bloom, 2004; Geyer *et al.*, 2007; Atasu *et al.*, 2008; Guide and Van Wassenhove, 2009; Govindan *et al.*, 2015).

Manufacturers can use their RSC for several different purposes. Examples are take-back of products for resale or take-back of components for reuse in the firm's service operations. Resale of products adds to the firm's revenue, while reuse of components reduces costs by replacing purchase (or internal fabrication) of virgin components. These two examples demonstrate that the RSC impacts the firm's financial performance. The purpose of this thesis is to examine the relationship between the firm's RSC and its financial performance. The specific set of research questions are detailed later in the thesis along with a definition of the literature gap the thesis aims to fill.

The remaining sections in thesis' introduction will 1) delineate the concept of the RSC, 2) describe the history of RSC-research, 3) present this thesis' research questions, and 4) limit the thesis' domain (i.e. limit the type of firm to which the thesis' results apply).

1.1 THE REVERSE SUPPLY CHAIN (RSC)

While the customer is the end-destination in forward supply chains, RSCs begin *and* end with the customer. Guide and Van Wassenhove (2002) define the RSC as five consecutive processes: 1) Product acquisition, which concerns acquiring used products (these are often labelled *core* products or simply *cores* in literature); 2) reverse logistics, which concerns the movement of core products to sorting facilities; 3) inspection, testing and sorting of products for the determination of quality and the right choice of recovery operation; 4) recovery operation; and 5) market development and remarketing, which concerns market creation and exploitation (Guide and Van Wassenhove, 2002 and 2009). Figure 1 shows the RSC. This thesis considers internal reuse of core items as an alternative to remarketing.

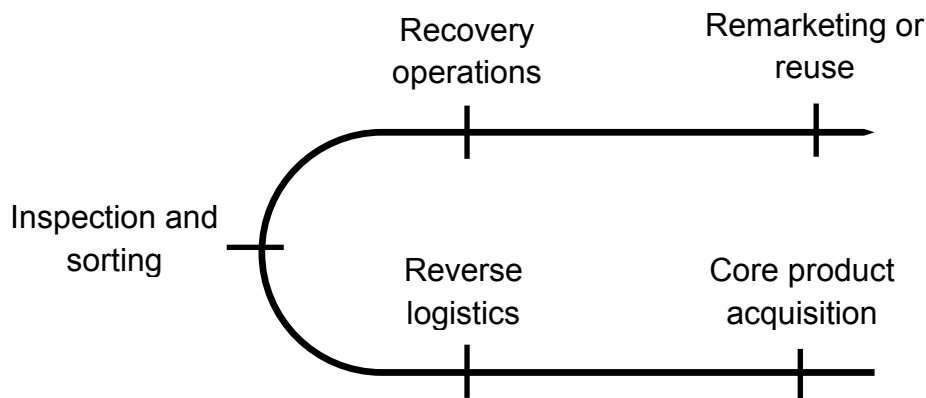


Figure 1 – Illustration of the RSC (Guide and Van Wassenhove, 2002)

Guide and Van Wassenhove's (2002) definition of the RSC as five consecutive processes is the prevalent perception of the RSC in literature. This definition is applied throughout the present summary thesis and all nine papers. The five processes in the figure are each umbrella terms for a series of subprocesses. For the recovery operations process, examples of subprocesses are product disassembly, component exchange, reassembly, and test of the finished recovered product.

1.1.1 THE RSC WITHIN THE CLOSED-LOOP SUPPLY CHAIN

Adding the RSC to the firm's forward supply chain results in what literature labels the CLSC (Govindan *et al.*, 2015). The CLSC first produces and delivers virgin products to the market, and then reuses them continuously in multiple cycles. Figure 2, 3, and 4 illustrate the RSC within the CLSC. Figure 2 from P-3 adds the five-step RSC to the forward supply chain of the firm. The dotted ar-

rows on the right-hand side of the figure illustrate the flow of core products back to the firm. Once returned, items go through the RSC. Items stay in the RSC loop until no longer useful.

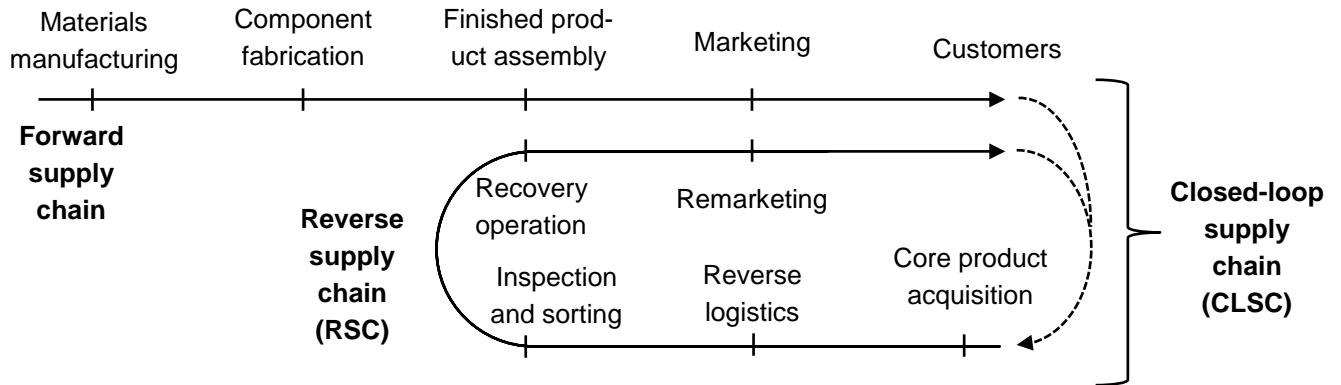


Figure 2 – The forward, reverse, and closed-loop supply chains (P-3)

In Figure 3 Geyer and Jackson (2004) depict the forward supply chain as a sequence of processes beginning with “Primary Materials Production” and ending with “Product Sale and Delivery”. When products are at their end-of-life, they enter the firm’s RSC. The RSC either disposes of products or recovers and re-inserts reprocessed items into the forward flow. As the figure shows, a RSC can reprocess complete end-products, individual components, as well as materials.

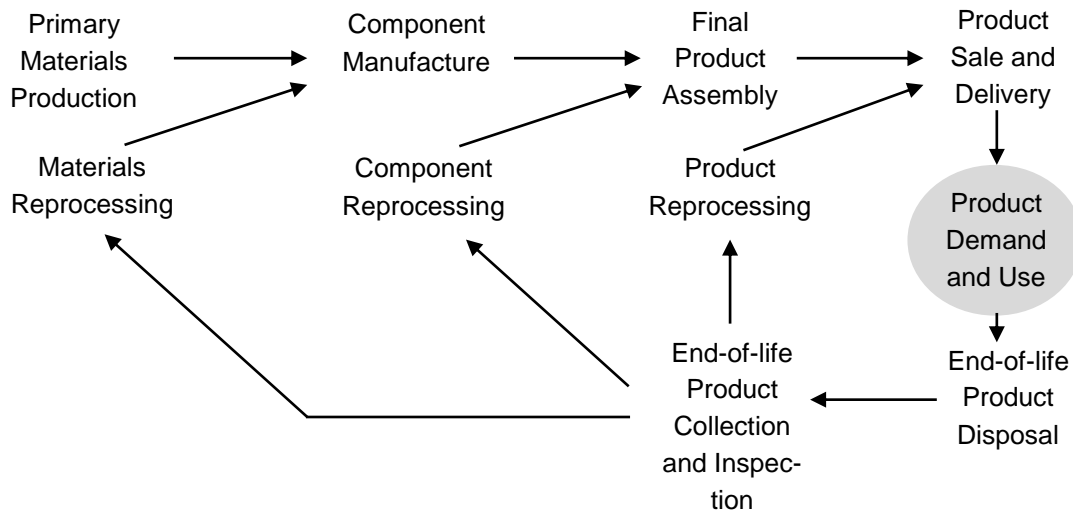


Figure 3 – The RSC seen within a closed loop supply chain (Geyer and Jackson, 2004)

In Figure 4 by Thierry *et al.* (1995), the central set of dark arrows and boxes represent the forward supply chain, while the grey arrows represent the RSC.

As the figure shows, there are several channels through which reverse flows can stream. Some options are relevant for complete end-products (e.g. direct reuse, repair, and refurbishing) while others are relevant for components and materials (e.g. remanufacturing and recycling). Cannibalization refers to the extraction of useful components from a product and disposing the remaining parts. This thesis will refer to cannibalization as component salvage.

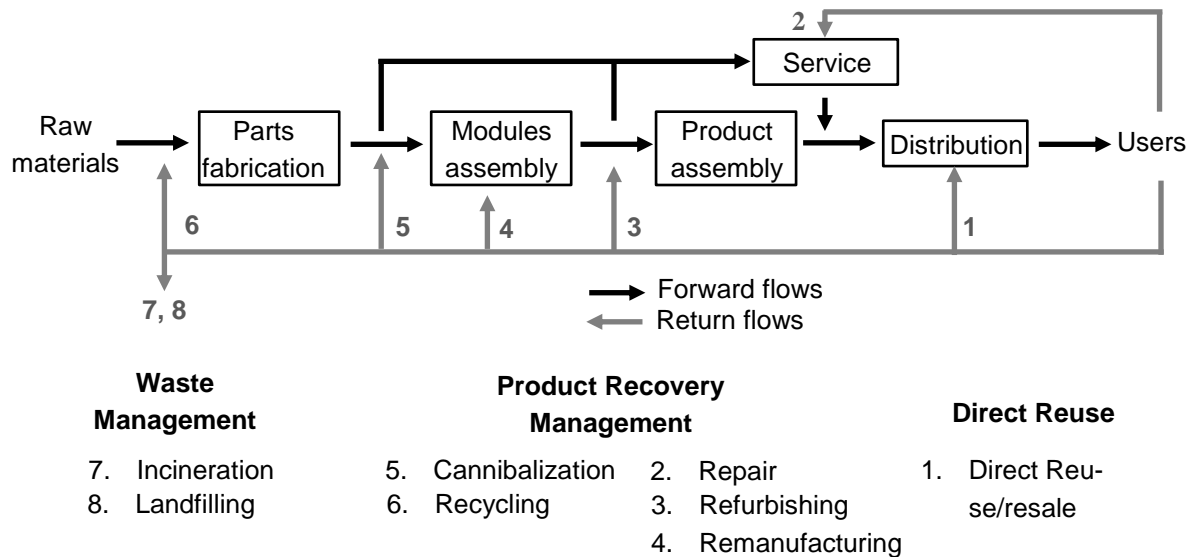


Figure 4 – The RSC within a closed loop supply chain (Thierry *et al.*, 1995)

The degree of integration between forward and reverse flows appears higher in the illustrations by Geyer and Jackson (2004) and Thierry *et al.* (1995) than in P-3. However, according to Hansen *et al.*, (2016) the question of integration between flows is not a binary choice, but instead a matter of choosing the right *degree of combination* between flows.

1.1.2 THE FUNCTIONS OF THE RSC

Although these graphical illustrations of the RSC within the CLSC appear rather straightforward, RSCs can entail a considerable amount of complexity because the RSC can conduct many activities simultaneously. Thierry *et al.* (1995) exemplifies this complexity by describing Xerox's RSC, which recovers the firm's "Green Line" series of copy-machines. Before presenting Xerox's RSC the thesis introduces the term *RSC-function*, which is useful for analyzing the content of any particular firm's RSC (P-3 and P-8).

A RSC-function is defined by three constituent elements: 1) a process (e.g. repair or remanufacturing), 2) an item (e.g. a complete end-product, a component, or a material), and 3) a financially contributing purpose (e.g. resale in secondary markets or reuse as spare parts). Take-back and refurbishing of end-products for resale to secondary markets is an example of a RSC-function. Another example is taking back products to disassemble them for the purpose of reselling components back to the original component-supplier. Both of the examples result in the financially contributing purpose of increased revenue for the firm. Other examples of RSC-functions are:

1. Refurbishment of end-products for resale in primary markets as a low-cost version of the virgin product
2. Refurbishment of end-products for resale in secondary markets
3. Refurbishment of components for reuse in refurbished products
4. Refurbishment of components for resale as spare-parts in the aftermarket
5. Resale of core materials upstream in the supply chain to current suppliers of virgin materials

Figure 5 illustrates a RSC that contains these five RSC-functions.

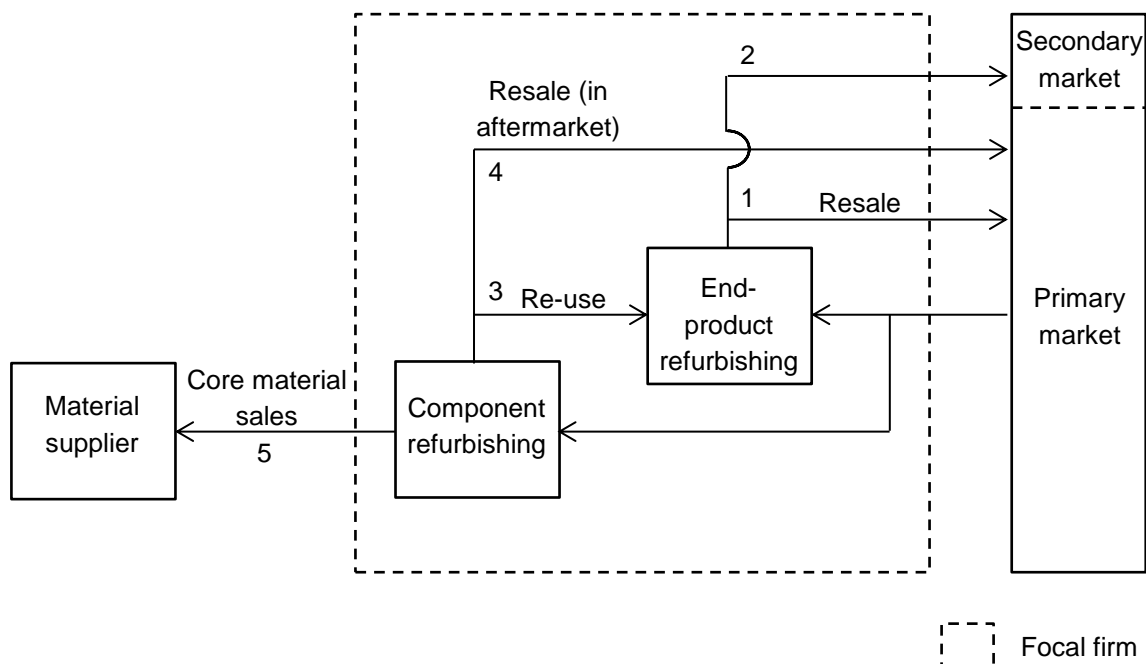


Figure 5 – A RSC with four RSC-functions

Figure 6 presents Xerox's CLSC, which consists of the firm's forward and reverse supply chains. In the figure black arrows represent the forward flow of goods and grey arrows represent flows in the RSC. In the forward supply chain,

suppliers deliver components and materials to a central component inventory, which delivers items to the firm's factories. Factories deliver assembled end-products to a central logistics centre, from where products are delivered to sales and service companies. Sales and service companies then deliver products and spare parts to customers.

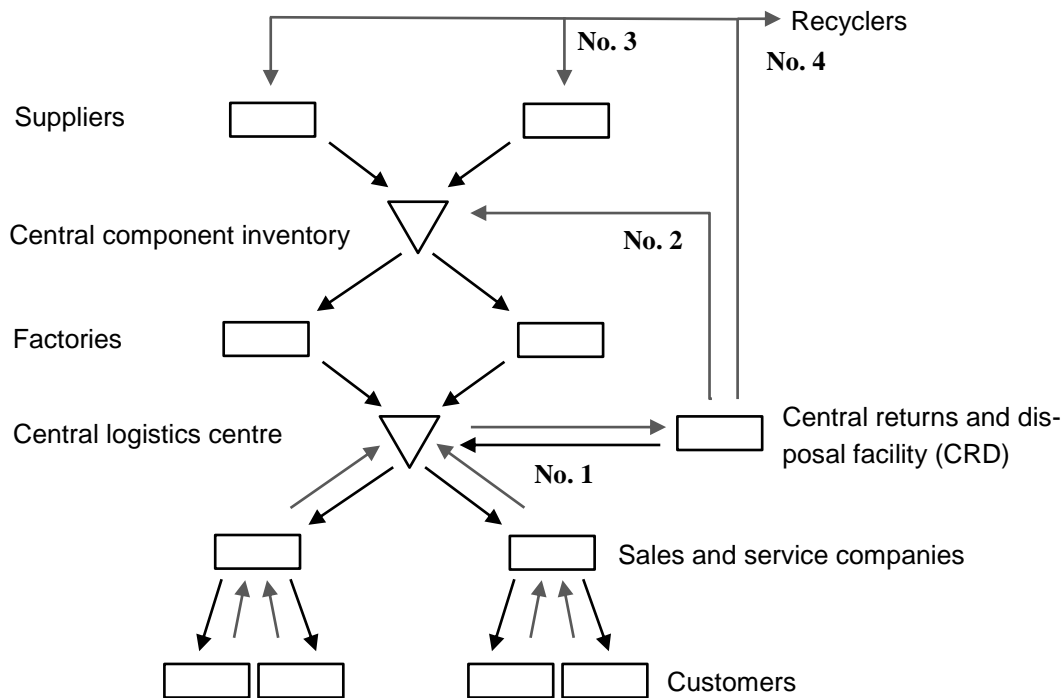


Figure 6 – Xerox' CLSC (adapted from Thierry et al., 1995)

The figure shows four RSC-functions in Xerox' RSC. RSC-function no. 1 takes back end-products, repairs these in the RSC's central return and disposal facility (CRD), and then sends products back to sales and service companies. RSC-function no. 2 takes back complete end-products and ships them to the firm's central component inventory through the CRD. When a factory receives an order from a sales and service company for a recovered product, the factory sends an order to the central component inventory for a core product. Then, the factory remanufactures the core product and ships the recovered product to the sales and service company. RSC-functions no. 3 and 4 disassemble products and ship core materials to either Xerox's own suppliers for recycling or to independent recyclers outside Xerox' forward supply chain. In total, Xerox's RSC contains four RSC-functions. Which RSC-functions that are generally available to manufacturers and how these RSC-functions contribute to the firm's financial performance are core questions in need of investigation, and it is the objective of this thesis to do so.

1.1.3 CORE PRODUCTS AS THE INPUT TO THE RSC

End-of-life and *end-of-use* are labels used for categorizing core products. End-of-life products are products that cannot be used any more in their core condition. End-of-life products may be recoverable, but require extensive exchange of parts. End-of-use products are returned from a customer when the customer is finished using the product. The quality of these products varies considerably, but is generally higher than that of end-of-life products. *Commercial returns* are those products that are returned by a customer, distributor, or retailer for any reason within up to 90 days of sale. The manufacturer receives these products from a reseller or distributor and must decide how to dispose the product. *Distribution returns* are packaging materials that a producer may want to reuse (Blackburn *et al.*, 2004; Guide and Van Wassenhove, 2009; Carrasco-Gallego *et al.*, 2012).

In essence, the labels end-of-life, end-of-use, and commercial return indicate in what condition an item is in, i.e. the item's level of quality when arriving at the firm's inspection and sorting facility. Commercial returns are of high quality and may be directly resalable or repairable. For end-of-use items, refurbishing or remanufacturing may be the right choices, while the right choice for end-of-life items may be salvaging reusable components and/or recycling materials (roughly following Guide and Van Wassenhove, 2009). In the context of this thesis all items regardless of label are grouped under the label core product. All core product enter the RSC and the RSC's inspection and sorting process determines the right recovery or disposal process.

1.2 THE HISTORY OF RSC RESEARCH

Historically, the RSC term is relatively new. An earlier and still widely used term that describes reverse product flows is reverse logistics. One of the earliest academic accounts of reverse logistics is Lambert and Stock (1981, p. 19), who describe reverse logistics as "going the wrong way on a one-way street". Later, Murphy and Poist (1989) defined reverse logistics as the "movement of goods from a consumer towards a producer in a channel distribution". Just as forward logistics, reverse logistics was defined rather narrowly as simply the movement of goods (albeit in the reverse direction). In the early 1990s Stock defined reverse logistics as logistics relevant in among others product returns, recycling, reuse, and waste disposal (Stock *et al.*, 2002). In the late 1990's Carter and Ellram (1998) related reverse logistics to the environmental management of materials by defining reverse logistics as "the process whereby companies can become more environmentally efficient through recycling, reusing, and reducing

the amount of materials used". Rogers and Tibben-Lembke (2001) separated reverse logistics from "green" logistics by limiting reverse logistics to the term covering the flow of products and materials in the "wrong way on a one-way street" regardless of environmental impacts. Rogers and Tibben-Lembke defines reverse logistics as follows:

"The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing or creating value or proper disposal" (Rogers and Tibben-Lembke 1999, p. 2).

The definition clearly resembles the Council of Logistics Management's definition of forward logistics from the late 1990s ("the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements"). The reverse logistics definition has an explicit focus on efficiency and cost effectiveness. Much research which carries the underlying belief that reverse product flows are a costly nuisance (or even trash) has focused on investigating ways of reducing costs of reverse logistics through e.g. optimal collection of core products, more effective vehicle routing, efficient reverse network designs, and inventory management (Stock *et al.*, 2002; Guide and Van Wassenhove, 2009; Govindan *et al.*, 2015). Indeed, the RSC has traditionally been viewed as a "costly sideshow to normal operations", an "unwanted stepchild of forward logistics", and "a nuisance, or worse, trash" (Stock *et al.*, 2002; Mollenkopf and Closs, 2005; Guide and Van Wassenhove, 2009).

By contrast, the RSC and CLSC concepts, which emerged in scholarly research along with the general (forward) supply chain concept, view the RSC as a value creator rather than a costly nuisance (Guide and Van Wassenhove, 2009; Govindan *et al.*, 2015). One of the earliest accounts of using the RSC value creation concept was the thought-piece by Thierry *et al.* (1995), which describes the retrievable value from reverse product flows. Thierry *et al.* (1995) use the term "strategic recovery management" to describe what later research labels the RSC. In a 2006 editorial in *Production and Operations Management*, Guide and Van Wassenhove, who are prolific authors of RSC research, argued for the use of a business perspective, where organizations seek to maximize the value from reverse product flows (Guide and Van Wassenhove, 2006) rather minimizing costs. This literature stream views RSCs as "potentially profitable business propositions" and investigates RSC-profitability issues (Guide and Van Was-

senhove, 2009). The general principle in the RSC business perspective literature stream is that the value that a RSC can provide the firm must exceed the costs of implementing and operating the RSC (Guide and Van Wassenhove, 2009). Figure 7 illustrates the business perspective. The figure shows the costs of the RSC on the left-hand side and the value that the RSC can provide the firm on the right-hand side.

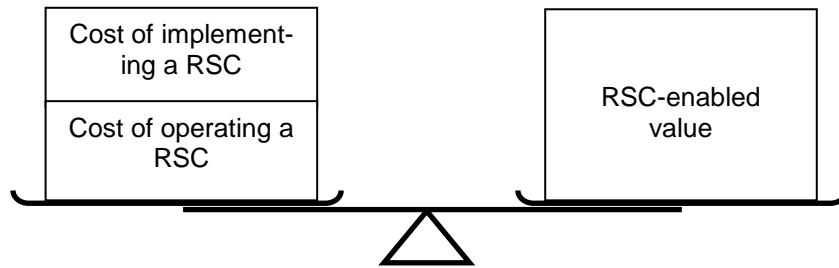


Figure 7 – The business perspective on the RSC (adapted from P-9)

This thesis interprets value as financial value, i.e. bottom-line profit. Other types of value, e.g. lower environmental impact, are not within the thesis' scope. When focusing on financial value only, the resulting balance of the scale constitutes the net contribution that the RSC makes to the firm's financial performance. This thesis applies the RSC business perspective and examines the relationship between the RSC and the firm's financial performance.

In extant literature some articles deal with financial evaluations of RSCs. Das *et al.* (2000) examine the economics of disassembly on a product-by-product basis; Geyer and Blass (2010) investigate the economics of cell-phone reuse and recycling; and Linton (2008) develops a model for determining the profitability of remanufacturing with resale of recovered products to the firm's primary market as a low-cost version of the virgin product. However, the understanding of RSCs is still very limited (Kocabasoglu *et al.*, 2007). A recent literature review by Huscroft *et al.* (2013) concludes that one of the greatest needs for scholarly research within the RSC-field is investigating ways to establish the RSC as a profit centre in the organization. Assessing the financial impact from the RSC differs from other investments in the firm's operating system (e.g. implementing a new layout or automating a process) because the RSC has an immensely scattered set of financial effects across the whole business. The firm's RSC is an integrated part of several functions (e.g. purchasing, logistics, manufacturing, inventory, and sales) and has more than 20 different cost parameters (P-8) that are difficult to discern from the traditional cost parameters of running a business. In addition, high-impact benefits of the RSC are often not included in financial

business-case analyses. For example, recovery and resale can create direct profits when using the simple “revenue minus costs”-lens. However, such analyses fail to include the RSC’s fiscal effects on the wider business. For example, increased probabilities of future virgin product sales and increasing service sales (P-5 and P-6). This thesis takes a more comprehensive view of the RSC’s fiscal effects on the business at large.

1.3 RESEARCH QUESTIONS

The overall objective of the thesis is to contribute to the RSC business perspective described in the earlier section by examining the relationship between the firm’s RSC processes and its financial performance. In the thesis, financial performance equates the firm’s bottom line profit, which the general finance vocabulary usually refers to as operating profit or earnings before interests and taxes (EBIT). This thesis aims to contribute to the RSC business perspective literature stream by answering the two questions illustrated in Figure 8.

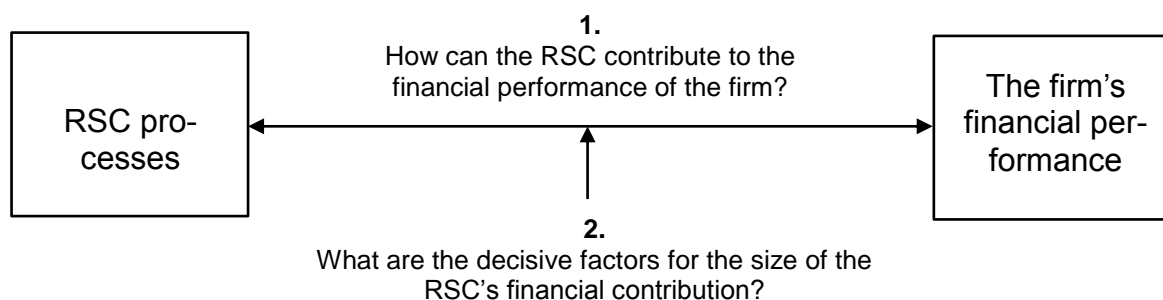


Figure 8 – The relationship between the RSC processes and firm’s financial performance

1.4 DOMAIN LIMITATION

The thesis limits the set of firms to Original Equipment Manufacturers (OEMs). An OEM is the original producer of a product that is the result on an assembly process (Karlsson, 2003). Alternative focuses could be independent remanufacturers, who buy purchase cores for remanufacturing and resale, or wholesalers. However, this project follows the extant stream of theory about RSCs to ensure the best foundation for the research. When the project is completed the development of models for independent remanufacturers, wholesalers, suppliers, etc. can build on the theoretical contribution this project produces.

For the purpose of this project an OEM is defined by the following description, which follows Karlsson (2003) and Geyer and Jackson (2004): 1) the OEM conducts end-product assembly and fabrication of some components in-house, while remaining components and all materials are purchased from suppliers; 2) the OEM's sells complete products and components as spare parts; 3) both complete products and components are durable and have potential for recovery and remarketing in primary as well as secondary markets. For the remainder of this paper an OEM with these characteristics will be referred to as "the focal OEM" or "the focal firm". Figure 9 illustrates the focal OEM in its supply chain.

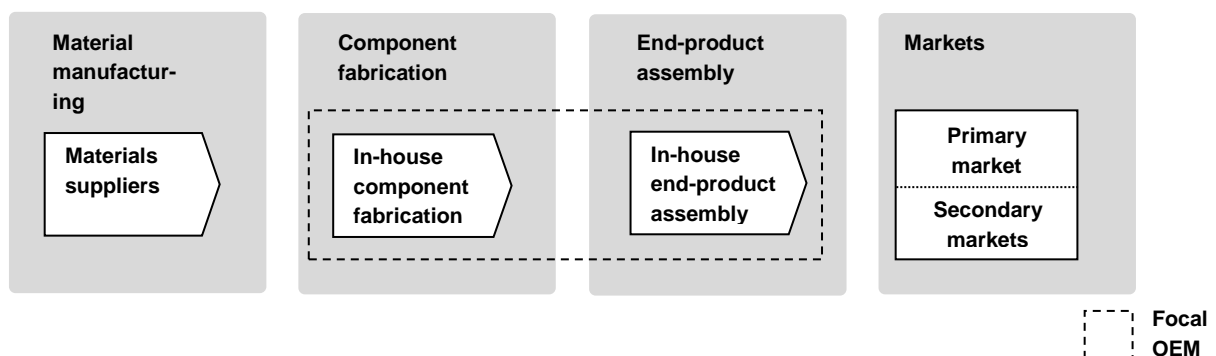


Figure 9 – The focal OEM within its forward supply chain (P-1)

1.5 HOW ANSWERING THE TWO RESEARCH QUESTIONS OF THE THESIS CONTRIBUTES TO THEORY

How to contribute to theory and practice is an important issue to any scientific study within operations management (OM), supply chain management, and other fields alike. The following section discusses what a theoretical contribution within OM is and how the answers to the two research questions of this thesis constitute such a contribution.

To define a theoretical contribution, the thesis applies an editorial by David Whetten from 1989 and a paper by John G. Wacker from 1998. David Whetten's editorial was published in the *Academy of Management Review* (AMR) during the author's time as the editor of the journal and John G. Wacker's paper was published in the *Journal of Operations Management*. Both papers have been heavily cited in the debate about the nature of a theoretical contribution. The two authors argue similarly about what the concept of a theory and a theoretical contribution is. Wacker's definition specifically addresses OM theory while Whetten's definition applies more broadly to most management fields including, for example, organization studies.

Whetten's and Wacker's theory definitions include three identical constituent elements: A theory must include 1) conceptual definitions of the theory's constructs, 2) a limitation of the theory's domain, and 3) defined relationships between constructs. In Whetten's definition, these elements are termed the "what", "when/where", and "how" of a theory. Both Whetten's and Wacker's definitions have a fourth constituent element. While Whetten stresses the importance of answering the "why" of the theory (i.e. explaining why constructs relate to one another as the theory claims they do), Wacker instead focuses on the theory's ability to predict occurrences of events. Wacker does mention the "why"-question, but devotes much less attention to it than Whetten.

Within general management and organization theory, which AMR publishes, explaining "why"-questions is the crux of a theoretical contribution. Answering the "why"-question means dealing with "the underlying psychological, economic, or social dynamics that justify ... the proposed causal relationships" (Whetten, 1989). Within OM a theoretical contribution often explains the "how" of a theory, while the "why" is oftentimes not explained. For example, a queuing theory explaining the relationship between customer arrival rate and queue length answers *how* the arrival rate and queue length are related. The "why", however, is not explained. The "why" is often embedded in what Wacker terms "fundamental laws" or laws derived from fundamental laws. For example, a lot sizing theory in inventory management may explain *how* the inventory carrying cost relates to the optimal ordering lot size, but not *why*. The answer to the why-question is given by the fundamental laws that underlie the expression for optimal lot size, e.i. the fundamental law that the inventory carrying cost equals the holding costs per item times the average amount of inventory. However, the OM field is broad and much OM theory deals with research questions that *do* require explanations of why relationships exist or do not exist.

This paragraph delineates the theoretical contributions of this thesis vis-à-vis the criteria of Whetten (1989) and Wacker (1998). The first research question (presented in Figure 8) is a relationship-defining *how*-question that concerns how the RSC relates to the financial performance of the firm. The answer to this question is a set of RSC-functions through which the RSC can contribute to the financial performance of the firm. The introduction presented two examples of such ways: 1) take-back and resale of products, and 2) take-back and reuse of components. The second research question examines factors that are decisive for the size of the RSC's contribution and whether the RSC indeed can make a positive contribution at all. As Figure 6 shows, the RSC's net contribution is negative if the costs of the RSC supersede the value that RSC produces for the firm. The set of factors that constitute the answer to the second research ques-

tion can help managers predict whether their firm will profit from pursuing an RSC opportunity. In essence, the second question is a *why*-question, because the factors that answer the question determine why some firms have profitable RSCs, while others do not.

The thesis is organized as follows: Section 2 reviews the RSC literature. Section 3 describes chosen set of methodologies. The thesis is paper-based rather than a monograph, so each individual paper details its own method. Section 4 and 5 answers the thesis' two research questions thematically. Sections 6 and 7 discuss results and present conclusions, contributions, limitations, and suggestions for further research.

2 LITERATURE REVIEW

The thesis' research questions concern how the RSC can contribute to the firm's financial performance and which factors determine the size of the RSC's contribution (and whether the RSC can make a positive contribution at all). The purpose of the literature study is to review the papers examining related questions. In addition, the review examines how literature defines the RSC. The review is developed as a separate journal paper that is part of thesis and placed as an appendix (P-2). The paper's headline is "How the reverse supply chain impacts the firm's financial performance: A manufacturer's perspective". The paper limits the domain to the same type of firms as the overall thesis, deals with the same two research questions as the thesis, and examines how literature defines the RSC. This section will summarize literature's RSC-definitions, while the literature review's remaining findings can be found within the paper itself.

Before summarizing the results of the paper, Figure 10 shows the distribution of review's selected papers among academic journals. The figure shows that the selected papers are thematically located within manufacturing and logistics management. Journals that publish general OR-papers are heavily represented because many papers apply OR-methods. Two journals represent the field of sustainability (Resources, Conservation and Recycling, and the Journal of Cleaner Production).

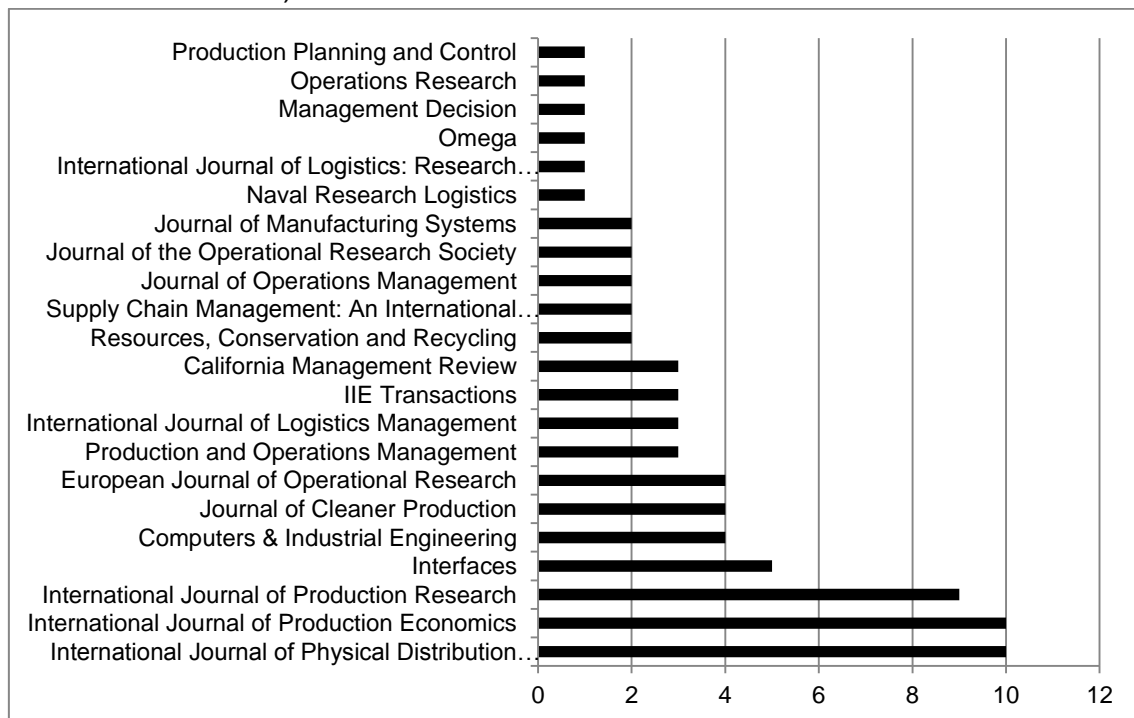


Figure 10 – The distribution of papers selected among academic journals (P-2)

Table 2 list the different definitions applied in the set of selected papers. Five papers define the RSC as this study as five interconnected processes (depicted in Figure 1). Another five papers apply the definition of the CLSC by Guide and Van Wassenhove (2006), which defines the CLSC as “a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time”. Seven papers apply the definition of reverse logistics by Rogers and Tibben-Lembke (1999). As the CLSC definition by Guide and Van Wassenhove (2006), Rogers and Tibben-Lembke describe the purpose of the RSC as “recapturing value or proper disposal.” Thierry *et al.* (1995), who apply the term strategic recovery management, also have the objective of value creation and define the objective of the RSC as recovering value from reverse product flows. All these definitions focus on extracting value from reverse product flows. This purpose, which is congruent with Guide and Van Wassenhove (2006), argue for the use of a business perspective in RSC-research. Larsen and Jacobsen (2016) discuss the differences between RSC, CLSC, and strategic recovery management. They conclude that the basic “nuts-and-bolts” operating system that conducts the physical processes that results in value creation is the RSC understood as the five processes depicted in the Figure 1.

Table 2 – RSC definitions in the selected papers in the thesis’ literature review

No.	Definition of RSC or related term	Original source	Times used*
1	"The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal"	Rogers and Tibben-Lembke (1999)	7
2	The RSC consists of “Product acquisition... Reverse logistics... Inspection and Disposition... Reconditioning... Distribution and Sales”	Guide and Van Wassenhove (2002)	5
3	“CLSC management is the design, control and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time.”	Guide and van Wassenhove (2006)	5
4	“from a business logistics perspective, the term refers to the role of logistics in product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal, and refurbishing, repair, and remanufacturing”	Stock (1998)	2
5	“Remanufacturing is “a production strategy whose goal is to recover the residual value of used products by reusing components that are still functioning well””	Debo <i>et al.</i> (2005)	2
6	“Remanufacturing is “an industrial process of returning a used product to at least its original performance, equivalent to or better than that of the newly manufactured product.”	Chapman <i>et al.</i> (2009)	1

7	"reverse logistics (RL) is defined as a process by which a manufacturing entity systematically takes back previously shipped products or parts from the point-of-consumption for possible recycling, remanufacturing, or disposal."	Dowlatshahi (2010)	1
8	"Reverse logistics is a process in which a manufacturer systematically accepts previously shipped products or parts from the point for consumption for possible recycling, re-manufacturing, or disposal."	Dowlatshahi (2000)	1
9	"Reverse logistics refers to the logistic management skills and activities involved in reducing, managing and disposing of hazardous or non-hazardous waste from packaging and products. It includes reverse distribution, which causes goods and information to flow in the opposite direction from normal logistic activities."	Kroon and Vrijens (1995)	1
10	"reverse logistics, which is a broader term and encompasses collection, transportation, inspection and sorting, inventory management, and production planning and scheduling of returned products."	Mitra (2007)	1
11	"Closed loop supply chains include traditional forward supply-chain activities and the additional activities of the reverse supply chain."	Mont <i>et al.</i> (2006)	1
12	"The reverse logistics processes generally are considered to include: authorization of returns, transportation, auditing, product disposition, and creating information about the kinds of products being returned and where they are coming from"	Trebilcock (2001)	1
13	"Product recovery management (PRM) encompasses the management of all used and discarded products, components, and materials that fail under the responsibility of a manufacturing company. The objective of product recovery management is to recover as much of the economic (and ecological) value as reasonably possible, thereby reducing the ultimate quantities of waste."	Theirry (1995)	1

* The number of times the selected papers use the definition

3 METHODS

Research can contribute to theory through either 1) exploring new territories to identify relevant research questions and variables; 2) building theory that answers research questions and defines relationships between variables; 3) testing theory to evaluate robustness, domain limits, and practical applicability; and 4) refining or developing theory to sharpen the theory's prediction abilities or fit new domains. This thesis contributes by building theory. Specifically, the thesis contributes by building theory about the relationship between the RSC and the financial performance of the firm.

Both Wacker (1998) and Meredith *et al.* (1998) divide the research methods for theory-building into the categories of analytical research methods and empirical research methods. According to Wacker (1998) each of these two categories contains three distinct research methods. Figure 11 illustrates the research methods within each category. In addition to the six research methods in Figure 11, Denyer and Tranfield (2010) consider the systematic literature review a seventh distinct method.

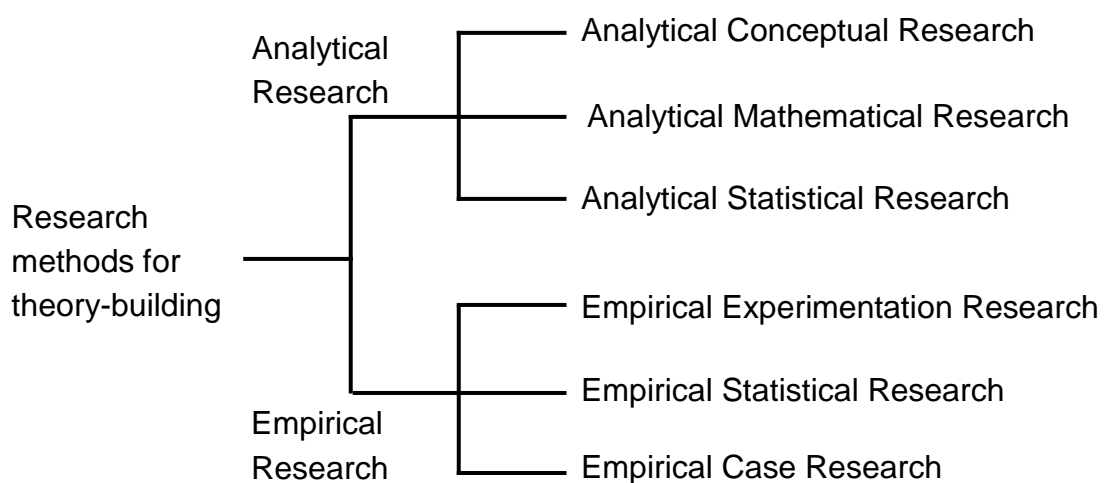


Figure 11 – Six research methods for theory building (Wacker, 1998)

The thesis contains a set of papers, each with their own individual research design. The set of papers apply analytical conceptual research, empirical case research, and the systematic literature review as methods. The dominant research method is empirical case research. The following two sections present the thesis' philosophical foundations and arguments for the use of case re-

search as the dominant research method. The methodology of individual papers is described in detail within each paper.

3.1 PHILOSOPHY OF SCIENCE IN LOGISTICS AND SUPPLY CHAIN MANAGEMENT, AND IN THIS THESIS

The theoretical field to which the thesis belongs is logistics and supply chain management, which the thesis considers subfields of the larger operations management discipline.

Logistics emerged as a "scientific" discipline in the early 1960s (Arlbjørn and Halldórsson, 2002) and academics have since the mid-1990s discussed the discipline's philosophical foundations in top journal publications. A cornerstone in this discussion was a series of papers in the *Journal of Business Logistics* by John Mentzer and colleagues, who concluded that positivism is the predominant approach in logistics research. Mentzer and Kahn (1995) describe positivism in the logistics discipline as an approach that perceives reality as objective and tangible, people as deterministic, and research findings as value-free and context-independent. However, since the 2000s logistics scholars have criticized the stance that positivism is the predominant research paradigm in logistics. Aastrup and Halldórsson (2008) go as far as criticizing the positivism-claim by saying that the claim is "not supported by comprehensive evidence, but is rather a legacy – or myth – that has been brought further". The authors argue that the logistics discipline has brought itself to an intellectual blind spot that will not be reversed unless the discipline allows for the use of alternative research approaches than the quantitative rational approaches such as mathematical modelling and simulations. Case study research constitutes such an alternative approach if the method is given an independent and complete role in the logistics discipline rather than a complementary role in the exploratory research phase.

One research paradigm that differs from the positivist realist paradigm is critical realism. Critical realism assumes an objective reality, but claims that reality is not directly accessible for the researcher. The researcher's knowledge of reality is instead theory-dependent (Aastrup and Halldórsson, 2008). The assumption of an objective reality to which the researcher has theory-dependent access forms the basis for all papers in this thesis. While P-3 explicitly applies the assumptions from critical realism (e.g. that research must identify underlying mechanisms that create events) the remainder of papers do not address the issue of philosophy of science directly.

3.2 THE ROLE OF CASE STUDY RESEARCH IN LOGISTICS AND SUPPLY CHAIN MANAGEMENT, AND IN THIS THESIS

From a positivist stance Mentzer and Flint (1997) describe the research process within logistics as a three-step sequence: 1) using qualitative methods (e.g. case studies) to induce a theory with larger applicability than the observed cases, 2) from this theory to deduce a set of testable hypotheses that define the relationship among concepts and then to test these hypotheses using quantitative methods (e.g. surveys or simulations), and 3) if the hypotheses are supported by the tests then to generalize the theory inductively to the population the sample was taken from. Mentzer and Flint describe this three-step sequence under the headline “Sound science” followed immediately by a discussion on methodological rigor in logistics research. The paper clearly indicates the role of case study research as a means to identify preliminary theory from which hypotheses can be deduced, i.e. an initial step in the overall research process.

The role of case study research in logistics advocated by Mentzer and colleagues was challenged by Lisa Ellram in 1996 with an article also published in the *Journal of Business Logistics*. Lisa Ellram argues that viewing case studies as relevant only in the exploratory phase is a misconception of the case study method. Case study research can in itself constitute the one and only method applied in a study. According to Ellram (1996) case study research serves the purpose of explaining and understanding a phenomenon using rich and in-depth data allowing “the researcher to really probe the how and why questions”.

Since the mid-1990s the use of the case study method has proliferated not only in the logistics discipline, but in the larger operations management discipline as well. The method is applicable where researchers have no or limited control, enables investigation of actual practice, and allows for a deep understanding of the nature and complexity of the research phenomenon (Meredith, 1989; Voss *et al.*, 2002; Mollenkopf *et al.*, 2007; Barrat *et al.*, 2011). A number of authoritative papers have emerged describing how case study research is conducted in a rigorous manner (e.g. Meredith, 1998, and Voss *et al.*, 2002). According to Meredith (1998) researchers naturally associate the case study approach with theory building, but insist that case research is useful for testing and extending theory as well. Voss *et al.* (2002) even label case study research as the “most powerful research methods in operations management, particularly in the development of new theory”.

The thesis has chosen the case study method because it enables the study of a focused phenomenon through the use of contextually rich data from real-world

settings. When evaluating the use of case research against Wacker's four characteristics of a theoretical contribution described in section 1.5, cases studies can develop contributions that match all four characteristics. A case study can evaluate the relationship between two constructs within a limited domain, and theory developed through case study research can "predict outcomes based upon past occurrences in similar cases" (Ellram, 1996).

The nine papers that are part of the thesis have used multiple cases (usually a sample of seven or eight cases). Multiple cases allow for using replication logic that strengthens findings' transferability (da Mota Pedrosa *et al.*, 2012; Miles *et al.*, 2014; Yin, 2014). All papers have used sampling criteria that match the characteristics of the focal firm defined in the thesis' domain limitation. In all papers, the totality of chosen cases includes a wide variety in both firm size and in industry type, which broadens finding's external validity. Differences in industry means differences in, for example, product technologies, customer requirements, product sizes, and logistical set-ups. These differences may expose distinct observations (Liebl *et al.*, 2016) and enable the investigation of similarities and differences across cases. Cross-case analysis makes theoretical generalizations possible (Ketokivi and Choi, 2014; Miles *et al.*, 2014).

The following sections 4 and 5 summarize the thesis' results by going through the thesis' two research questions thematically. While section 4 summarizes the results of the thesis' papers that add to the understanding of how the RSC can contribute to the financial performance of the firm, section 5 summarizes the results from the thesis' papers that add to the understanding of which factors are decisive for the size of the RSC's financial performance contribution.

4 HOW THE RSC CAN CONTRIBUTE TO THE FINANCIAL PERFORMANCE OF THE FIRM

As delineated in sections 1 and 2 the RSC can contribute to the financial performance of the firm by either increasing the firm's revenue or reducing the firm's costs. Section 4.1 details how the RSC can increase the firm's revenue, while section 4.2 concerns the RSC's cost reduction possibilities.

4.1 INCREASING THE FIRM'S REVENUE

A recurring challenge in examining the financial contribution of the RSC is the assessment of the RSC's revenue impact (Thierry *et al.*, 1995; Mollenkopf and Closs, 2005). How to identify and utilize sources of RSC-enabled revenue are questions that transcend the functional boundary between marketing and operations functions, and calls for cooperation between marketing and operations management research communities (P-1). Although the marketing-operations interface has received considerable attention within academia (e.g. Tang, 2010), the particular relationship between marketing and RSC-operations is under-researched (e.g. Ilgin and Surendra, 2010). According to Guide and Van Wassenhove (2009) marketing research communities lack the interest of investigating RSC-topics. Indeed, searching for RSC and related issues in marketing journals show that the topic is rarely examined. A special issue of the journal *Industrial Marketing Management* acknowledges the underexplored problem (Lee and Lam, 2012; Chan *et al.* 2012).

To examine the relationship between the RSC and the firm's revenue the thesis has conducted two studies, which are detailed in P-1 and P-3. The first of the two studies examines 1) which revenue streams the RSC enables the firm to utilize and 2) how these streams are utilized in industrial practice. The paper applies an exhaustive view of how the RSC can provide the firm with increased revenue. The second study (P-3) focuses specifically on how the RSC can lift the firm's virgin product revenue by increasing the firm's ability to compete through the firm's chosen competitive strategy. The following sections detail the findings from the two studies by summarizing the sources of RSC-enabled revenue and how manufacturers utilize these sources in industrial practice.

Following P-1 the thesis defines RSC-enabled revenue as "a continuous stream of income received by a firm from resale of items processed in the firm's RSC or

from added virgin product sales enabled by the RSC”. The definition contains two revenue categories: 1) revenue achieved through the RSC’s disposition strategies for core products and 2) increased virgin product revenue enabled by the RSC. Following this definition the thesis divides RSC-enabled revenue into these two categories, which section 4.1.1 and 4.1.2 detail.

4.1.1 REVENUE THROUGH THE FIRM’S DISPOSITION STRATEGIES FOR CORE PRODUCTS

A number of revenue streams that are available to OEMs, stem from utilizing the disposition strategies inherent in a firm’s RSC. A disposition strategy is a choice of what to do with a core product or component that has returned from the market. Every revenue streams sells an item to a buyer group using a disposition strategy. Using the three dimensions *item*, *disposition strategy*, and *buyer group* in a three-dimensional matrix, Figure 12 captures all potential revenue streams available through the firm’s disposition strategies. The figure contains a total of 84 revenue streams representing the result from multiplying the number of components on each axis. The content of each axis in the figure is the result of a literature review conducted in P-1.

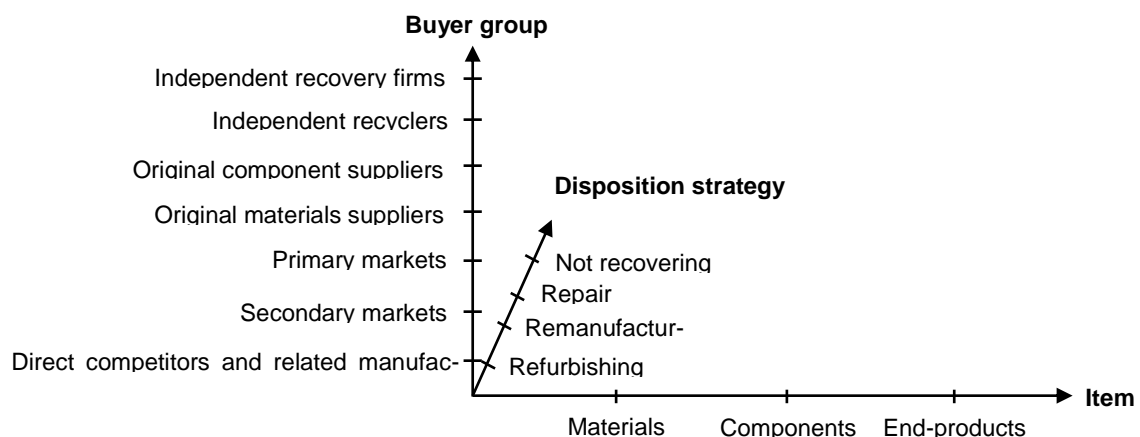


Figure 12 – The three dimensions that capture 84 potential revenue streams (P-1)

Figure 12 contains the revenue streams available to OEMs by utilizing the firm’s disposition strategies. The set of 84 revenue streams does, however, contain numerous illogical streams, for examp “resale of recovered materials to independent recyclers”. This stream of revenue is illogical because independent recyclers’ raison-d’être is recycling materials. So these firms are not buyer groups for materials already recycled. By excluding illogical revenue stream a set of revenue streams *logically available* for OEMs emerges. P-1 details the

exclusion procedure, which is purely analytical in nature. Table 3 shows that the remaining number of RSC-enabled revenue streams that are logically available to OEMs is ten. The table denotes the revenue streams as A1, A2, etc. As an example, B1 indicates a revenue stream where the firm resells recovered components to the firm's primary market customers. Dark intersections in the table indicate illogical revenue streams.

The table differs from Figure 12 by lacking the disposition strategy axis. P-1 details that to utilize a revenue stream the OEM must select the strategy that best fits the buyer group's purchasing criteria. Therefore, the choice of disposition strategy depends on the buyer group choice and is not a separate decision. Consequently, a revenue stream's constituent elements are reduced to item and buyer group. In addition, the table shows that items can be resold in either core or recovered condition.

Table 3 – RSC-enabled revenue streams (A1-B5 represent individual revenue streams) (P-1)

		Category A			Category B		
IRFs	1		A1	A2			
Independent recyclers	2	A3					
Org. component suppliers	3		A4				
Org. material suppliers	4	A5					
Primary markets	5					B1	B2
Secondary markets	6					B3	B4
Direct comp. and related man.	7					B5	
		Materials	Compo- nents	End- products	Materials	Compo- nents	End- products
		Core			Recovered		

Figure 13 depicts the set of revenue streams from Table 3 as arrows on the illustration of the thesis' focal firm from section 1.4. The beginning of each arrow symbolize the location in the firm's supply chain where each RSC-enabled revenue stream originates (where the sellable item is "produced"), and the end of each arrow points towards a buyer group.

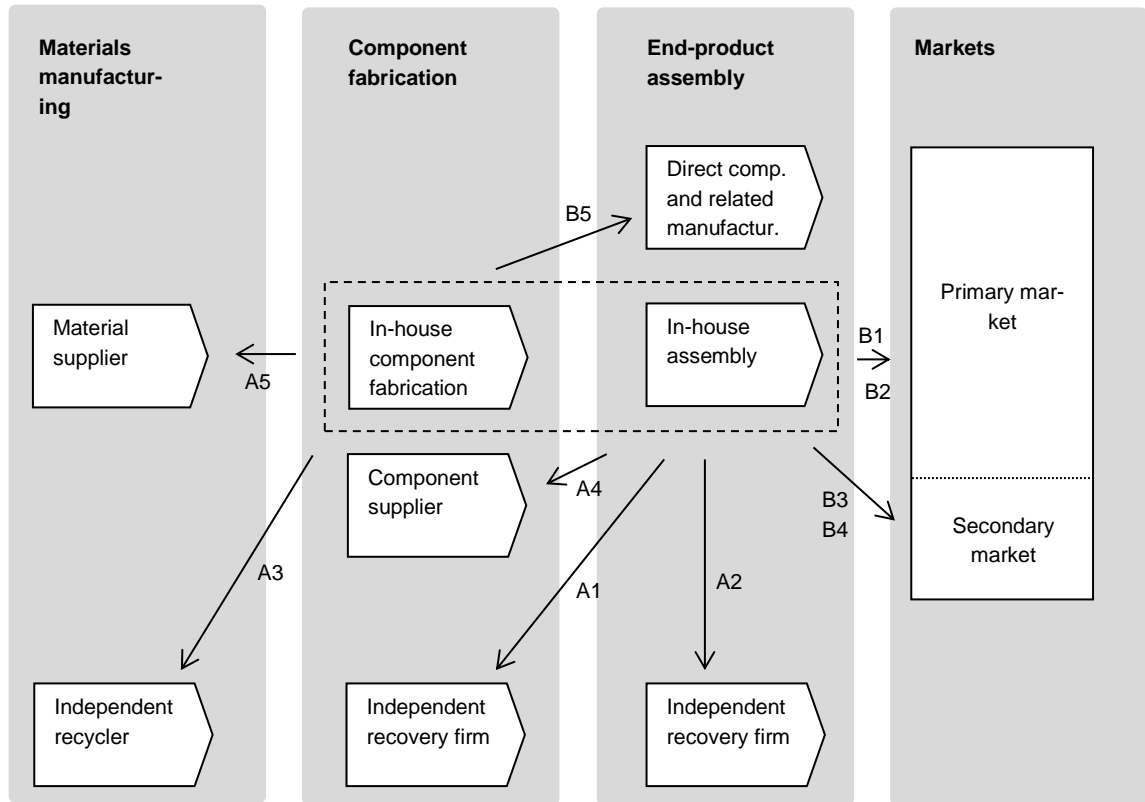


Figure 13 – Twelve revenue opportunities for the focal OEM (adapted from P-1)

4.1.2 RSC-ENABLED REVENUE THROUGH INCREASED SALE OF VIRGIN PRODUCTS

The RSC enables added virgin product revenue through both attraction of new customers and retention of current customers (e.g. Jayaraman and Luo, 2007; Govindan *et al.*, 2015). The thesis has examined the impact of the RSC on the virgin product revenue using a literature-based conceptual approach (P-1) and an empirical approach (P-3). The following paragraphs summarize these two approaches beginning with the literature-based conceptual approach in P-1.

From literature P-1 extracts two distinct ways through which the RSC can increase the firm's virgin product revenue: The firm can add RSC-enabled services to their total product offering, which increases the value of the firm's offering, and the firm can augment the firm's brand by including environmental responsibility among customers' brand image associations. Both result in either larger market share or increased revenue through price increases. Examples of RSC-enabled services are repair services, take-back of end-of-life, a liberal return policy, and an extended product warranty that includes remanufacturing of

a product or free replacement of a defective product with a remanufactured product (Prahinski and Kocabasoglu, 2006; Cohen *et al.*, 2006; Jack *et al.*, 2010; Souza, 2012). A “green” brand image is a well-examined driver of revenue. The RSC can contribute to the firm’s green brand image, because the RSC reuses materials and reduces waste (Atasu *et al.*, 2008). A strong brand image creates customer loyalty, higher willingness-to-pay among buyers, and barriers against competitor entry (Jayaraman and Luo, 2007; Mollenkopf and Closs, 2005; Kotler and Keller, 2009), which all increase the firm’s revenue.

Because the firm’s ability to compete on their chosen competitive strategy impacts the firm’s virgin product revenue, the study in P-3 examines the RSC’s impact on the firm’s competing ability. Literature clearly asserts that the RSC *can* contribute to the firm’s competitive strategy (e.g. Stock *et al.*, 2002, Jayaraman and Lou, 2007, Loomba and Nakashima, 2012), yet the question of how the RSC can (and does) contribute remains unexplored. Demonstrating how the RSC can contribute to the competitive ability of the firm helps change the RSC-perception of practitioners from that of a costly nuisance to that of a value creator. Such a perception change may increase practitioners’ use of the RSC, which not only would contribute to the firm’s competing ability, but also contribute to the reduction of waste and the emerging resource scarcity problem in society at large (Diener and Tillman, 2015). By examining seven cases P-3 investigates how the RSC can impact the two generic competitive strategies developed by Michael Porter (1980): Cost Leadership and Differentiation. The results show that the RSC can play a strategic role to both competitive strategies. Figure 14 illustrates how this can occur.

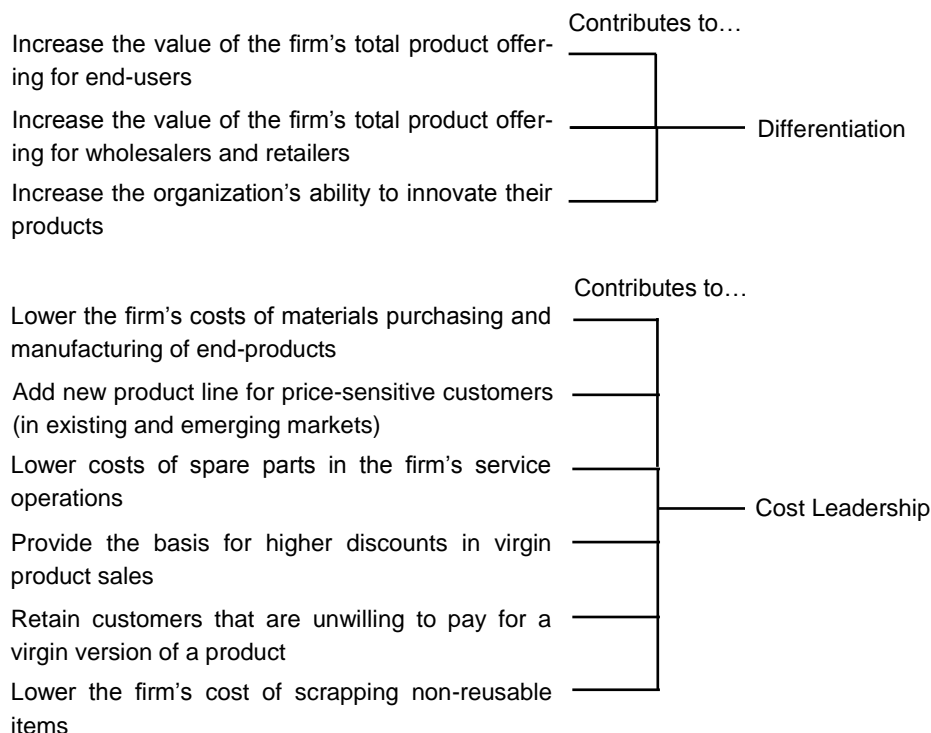


Figure 14 – The RSC’s opportunities for contributing to the firm’s competitive strategy (P-3)

The figure shows three ways the RSC can contribute to the Differentiation strategy and six distinct ways the RSC can contribute to the Cost Leadership strategy. To contribute to a Differentiation strategy the RSC can increase the value of the firm's total product offering towards customers as well as partners in the firm's downstream distribution network by adding RSC-enabled services to the firm's product offering. In addition, the RSC offer an effective and smooth return process and liberal return policy. One example of a RSC-enabled service is immediate replacement of a defective product with a recovered product. In addition to increasing the value of the firm's product offering to customers and distributors, the RSC can contribute to a Differentiation strategy by increasing the firm's ability to innovate their product. The RSC can extract information about why customers return product and when customers consider a product as being end-of-life. This information can feed into the product development department. To contribute to a Cost Leadership strategy, the RSC can 1) lower the firm's operating costs in the forward operations (section 4.2 will detail these possibilities), which leads to the possibility of reducing virgin product prices; 2) attract price-sensitive market segments by introducing recovered products as a low-cost product line extension and in the case rebuying by giving discounts to customers for allowing the firm to take back the customer's end-of-life product; and 3) reducing the firm's costs of scrapping by reusing instead of scrapping.

4.1.3 DIRECT SALES OF THE RSC'S PROCESSES AS A SERVICE

P-5 tested the exhaustiveness of the set of revenue opportunities presented the previous two sections using a single case study. In the study a catalyst manufacturer decided to identify which revenue opportunities from Table 3 the firm could apply profitably. During the screening process, the firm identified an additional revenue opportunity: to sell the services of the RSC directly to customers (e.g. an extra fast repair service or selling remanufacturing of a product as a service). This adds to the revenue streams identified in P-1.

4.1.4 THE INDUSTRIAL USE OF RSC-ENABLED REVENUE SOURCES

A revenue stream's logic availability (described in section 4.) does not guarantee profitability if and when a firm decides to pursue the revenue stream. Therefore, P-1 includes a research question about the industrial use of the revenue streams identified in the study. For a set of eight cases, the study specifically examined both the pattern in the industrial use of the streams and the factors that explain the pattern. While the utilization pattern is presented in this section of the thesis, the explaining factors are described in the thesis' section on decisive factors for the RSC's contribution to the firm's financial performance.

The study examines the industrial use of 12 revenue streams of which ten streams are available through the firm's disposition strategies for core products and two revenue streams enabled by the RSC through the inclusion of RSC-enabled services or augmentation of the brand image. Table 4 shows the pattern of revenue stream utilization with the set of cases. The table's columns show case firms, while the table's rows show the 12 revenue streams. Black squares indicates a utilized revenue stream in the given firm.

Table 4 – Cross-case utilization pattern (P-1)

		Case firms							
		1	2	3	4	5	6	7	8
A1	Sales of core components to IRFs								
A2	Sales of core end-products to IRFs								
A3	Sales of core materials to independent recyclers								
A4	Sales of core components to original component suppliers								
A5	Sales of core materials to original material supplier								
B1	Sales of recovered components to primary market								
B2	Sales of recovered end-products to primary market								
B3	Sales of recovered components to secondary markets								
B4	Sales of recovered end-products to secondary markets								
B5	Sales of recovered components to direct competitors or related man.								
C1	Added sales of virgin products through RSC-enabled services								
C2	Added sales of virgin products through brand image augmentation								


 Utilized revenue stream

Table 4 shows that streams A1-2 and A4-5 are not utilized by any case firm and that A3 is utilized by three firms out of eight. Unlike revenue streams A-1-5 revenue streams B1-5 show a quite consistent usage pattern across the eight cases. B1-5 appears to be used in bundles. Three of the eight cases utilize all revenue streams, while the remaining cases use none. While B5 and C2 are unutilized, stream C1 is utilized by all case firms. Overall, six of 12 streams are utilized in the entire case set. Section 5 concerning the decisive factors for the RSC's contribution to the firm's financial performance examines the factors that can explain the pattern in presented in Table 4.

4.2 REDUCING THE FIRM'S COSTS

While section 4.1 presented how the RSC can contribute to the financial performance of the firm by increasing revenue, this section presents the ways a RSC can contribute by reducing the firm's costs. P-4 examines the relationship between a firm's RSC and overall operating costs by identifying the RSC-enabled opportunities for cost reduction.

Guide *et al.* (2003) state that RSC-profitability depends on the quality and quantity of returned items, and on the demand for recovered items. This statement holds true for resale of recovered items, where the RSC-costs are compared with the revenue the items' sale realizes. However, when the objective is cost reduction through internal reuse of returned items rather than resale, the realizable revenue is replaced in the comparison by the avoidable costs of purchased materials and internal production. The thesis formally defines a RSC-enabled cost reduction opportunity as "a possibility for a firm to reduce the operating costs of its forward supply chain through the use of the firm's RSC".

The objective of P-4 is to identify the cost reduction opportunities available for OEMs. The study's findings show that the RSC enables a variety of cost reduction opportunities. Most opportunities concern the replacement of internal production costs through the reuse of complete end-products or of components. One example that has received attention in literature is avoiding production costs for those spare-parts that the firm uses in its servicing of products that are no longer manufactured, but still installed with customers (Inderfurth and Kleber, 2013). For components fabricated in-house, recovery reduces materials purchasing costs, while recovery of components that were originally purchased lowers the costs of purchasing virgin components. Table 5 summarizes P-4's findings and shows whether the source of the opportunity presented in P-4, is either extant literature, the study's case research, or both. An additional finding in P-4's case study is that even though product recovery is known to most case firms, the actual use is limited.

Table 5 – The RSC's cost reduction opportunities identified in P-4

Cost reduction opportunity	Literature review	Case study
Replacing manufacturing of virgin end-products through direct reuse of returned non-defect products	X	X
Replacing manufacturing of virgin end-products through recovery of used or defect products	X	X
Replacing internally manufactured virgin components through recovery of used or defect components	X	X
Replacing purchased virgin components through recovery of used or defect components	X	
Reducing the cost of writing off returned non-defective products or components	X	
Replacing purchase of virgin materials for in-house component fabrication	X	
Reducing external cost of quality	X	X
Reducing landfilling costs through recycling		X

Five of the eight RSC-enabled cost reduction opportunities concern replacing the costs in the firm's forward operations for purchasing virgin materials, manufacturing virgin components, and assembling virgin end-products. End-products entail the highest amount of value so replacing an assembled virgin end-product with, for example, a repackaged product returned from a distributor, constitutes the greatest cost reduction opportunity. Whether recovery is more cost effective than virgin product manufacturing determines the contribution of the RSC to the firm's financial performance. Section 5 deals with the factors that impact the size of the contribution and whether the RSC can make a positive contribution at all.

5 THE DECISIVE FACTORS FOR THE RSC'S FINANCIAL CONTRIBUTION

The papers P-6 and P-7 have examined the factors that impact the RSC's contribution to the firm's financial performance. While P-7 uses a literature study and a set of cases for a qualitative identification of factors, P-6 uses three cases to, first, qualitatively identify the influencing factors and, second, quantitatively assess the relative impact of factors to identify the *decisive* factors. Because the set of decisive factors depend on the type of RSC (resale differs vastly from reuse), both studies examine a set of predefined RSC-functions. The following sections will summarize the findings from these two studies. In addition to P-6 and P-7, P-1 has studied the factors that impact the industrial utilization of the RSC-enabled revenue streams. This will also be summarized in the sections.

5.1 THE DECISIVE FACTORS FOR THE RSC'S FINANCIAL CONTRIBUTION

To establish the RSC as a profit-creating entity within the organization and to conduct research that enables firms to do so, academics and managers alike need a better understanding of the factors that are decisive for the RSC's contribution to the firm's financial performance. This thesis contributes by providing a systematic examination of 1) which factors influence the RSC's contribution and 2) the relative impact of these factors. The set of decisive factors emerge from addressing these two questions.

If managers are familiar with the factors that decisive for the RSC's contribution to the firm's financial performance, they have a strong and immediate set of indicators for whether their current (or potential) RSC contributes to the firm's financial performance. In addition, factor-familiarity focuses attention to the real barriers and platforms for the RSC's profit creation. For academics, knowing the factors' relative impact focuses research on the factors that matter for the RSC's contribution. Vast amounts of studies are published concerning subjects such as reverse network design, reverse transportation, and inventory management (Ilgin and Surendra 2010; Sasikumar and Kannan 2008a; 2008b; 2009). The question, which P-6 and P-7 address, is whether these well-researched issues have the largest impact on RSC-profitability or whether scholars have focused on issues of lesser impact vis-à-vis the RSC's financial contribution.

P-7 identifies factors that influence the RSC's financial performance contribution by scanning literature for factors and by using qualitative data from three cases. The paper explicitly divides factors into 1) direct influencers and 2) antecedents to direct influencers. Figure 15 depicts the division.

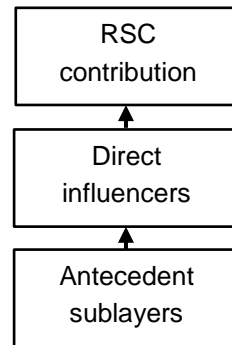


Figure 15 – The RSC's contribution and influencing factors (P-7)

The study develops a set of propositions that link an antecedent to the RSC's financial contribution through a direct influencer. Table 6 presents the set of propositions. For example, proposition no. 2 links the market value of a core product to the RSC's financial performance contribution because the market value of a core product impacts the OEM's core product acquisition costs. The market value of a core product is often determined by the interest on the core product from third parties (independent recovery firms). Each proposition is identified either through the use of literature or the study's case research. Propositions 9 and 11 are, however, deduced from the case study and suggested as a further research issue.

Table 6 – Propositions linking antecedents to the RSC's contribution

No.	Proposition	Literature	Case study
1	The type of relationship between OEM and customer impacts the cost of acquiring core products	X	
2	A high market value of a core product impacts the RSC-profitability negatively by increasing the OEM's product acquisition costs	X	
3	A high number of tiers on the OEM's downstream supply chain impacts the RSC-profitability negatively by increasing the OEM's product acquisition costs		X
4	The distance between customer and sorting facility impacts profit of RSC through in- or decreasing reverse logistics costs		X
5	The weight of core products impacts profit of RSC negatively because of reverse logistics costs		X
6	The design of the reverse logistics network and mode of collecting core products impacts RSC-profitability by in- or decreasing reverse logistics costs	X	
7	A high degree of difficulty of making the sorting decision increases the costs of run time per item and the level of equipment and skills needed, which impacts the RSC-profitability negatively		
8	Overestimating quality has a negative effect on RSC-profitability by increasing unnecessary recovery operations costs	X	
9	The ease of disassembly impacts RSC-profitability by affecting the costs of the recovery operation		
10	A low volume of cores available increases the costs of reverse logistics, inspection, sorting, and recovery and therefore impacts the RSC-profitability negatively		X
11	The internal cost of developing markets for recovered items and the continuous effort of remarketing impacts RSC-profitability negatively		
12	A high customer WTP for recovered items impacts the RSC-profitability positively	X	
13	A high degree of virgin product cannibalization impacts RSC-profitability negatively	X	
14	The value of core materials impacts RSC-profitability because extraction of materials requires the full breath of potentially costly disassembly		X
15	A high degree of customization and low reconfigurability of components decreases the value of a recovered component because the amount of potential buyers is lower		X
16	Low value of individual products impacts the profits negatively because the potential for cost reductions achievable through replacing virgin products with recovered products is low		X

The propositions explain how each antecedent prohibits or advances the RSC's financial contribution. Using the set of propositions managers are better equipped to influence the financial performance contribution of their firm's RSC. A manager might, for example, 1) ease disassembly through product design changes or advanced technology, 2) lower products' weight through lightweight materials, or 3) address markets with a higher willingness-to-pay for recovered products.

While P-7 identifies factors that influence the RSC's financial performance contribution, P-6 examines the relative impact among factors. The study, which is

limited to direct influencers only, examines factors for the following three RSC-functions:

1. Refurbishing of core products for the purpose of resale to primary and secondary markets, which results in added revenue
2. Refurbishing of core components for reuse for the purpose of avoiding purchasing virgin materials and manufacturing virgin components
3. Reuse of packaging materials for the purpose of replacing the purchase of virgin packaging materials

The study has chosen this set of RSC-functions because of the set's relevance for OEMs and the set's *cascading nature* (products that cannot be reused as complete products cascade down to the next RSC-function that strips unrecoverable products for recoverable components). Guide and Van Wassenhove (2006) recommend studies of RSC's with cascading RSC-functions.

The study applies the analysis sequence illustrated in Figure 16 for each of the three RSC-functions. First, the study identifies direct influencers of RSC-profitability; second, the study quantifies each influencer; third, the study calculates the profit (or loss) of each RSC-function; and fourth, once each RSC-function's profit is calculated, the study analyses the relative impact of each influencer by measuring the sensitivity of the calculated profit by increasing each factor one-by-one by 20%. For every increase of a factor the study observes the impact on profitability. The factors with the highest profitability impact are extracted from the study as the decisive factors of RSC profitability.



Figure 16 – Analytical sequence in P-6

5.1.1 RSC-FUNCTION 1: REFURBISHING OF CORE END-PRODUCTS FOR THE PURPOSE OF RESALE TO PRIMARY AND SECONDARY MARKETS

Figure 17 shows *how much* each factor impacts the RSC-function's financial performance contribution. The figure shows that 1) if the recovered product's sales price increases by 20%, then the RSC's financial contribution by 17%; and 2) if reverse logistics costs increase by 20%, then the RSC's financial con-

tribution changes by less than a half percent. The numbers in the figure, which are also measured in percent, represent the change in the RSC's financial contribution as an *absolute* number. If income-relevant numbers (e.g. the sales price) increase, then the contribution changes in the positive direction and if cost-relevant numbers (e.g. reverse logistics costs) increase, then the contribution changes in the negative direction.

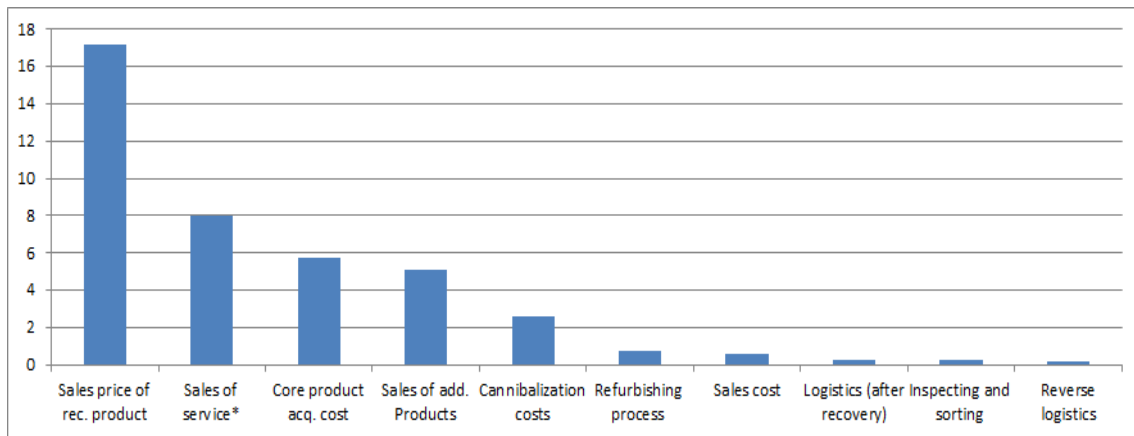


Figure 17 – Relative impact of factors for RSC-function no. 1

The figure clearly indicates that the decisive factors for the RSC's financial contribution are 1) the sales price for a recovered product, 2) the net earnings from sales of service that are enabled by the sale of a recovered product, 3) the core product acquisition cost, 4) the value of the probability increase for selling additional products to the customer of a recovered product, and 5) the lost profits from a cannibalized virgin product sale. All other factors including all process costs have close to zero impact on the RSC's financial contribution.

5.1.2 RSC-FUNCTION 2: REFURBISHING OF CORE COMPONENTS FOR INTERNAL REUSE

For a RSC-function that refurbishes core components for the purpose of reusing these internally, Figure 18 shows the impact distribution among factors. The figure shows the avoided costs of manufacturing an equivalent virgin product and the refurbishing as the decisive factors for the RSC's financial performance contribution. 84% of the recovery costs are constituted by the costs of the virgin subcomponents used in the recovery process. Reverse logistics costs as well as inspection costs and the avoided scrapping costs have a minimal impact on the RSC's financial performance contribution.

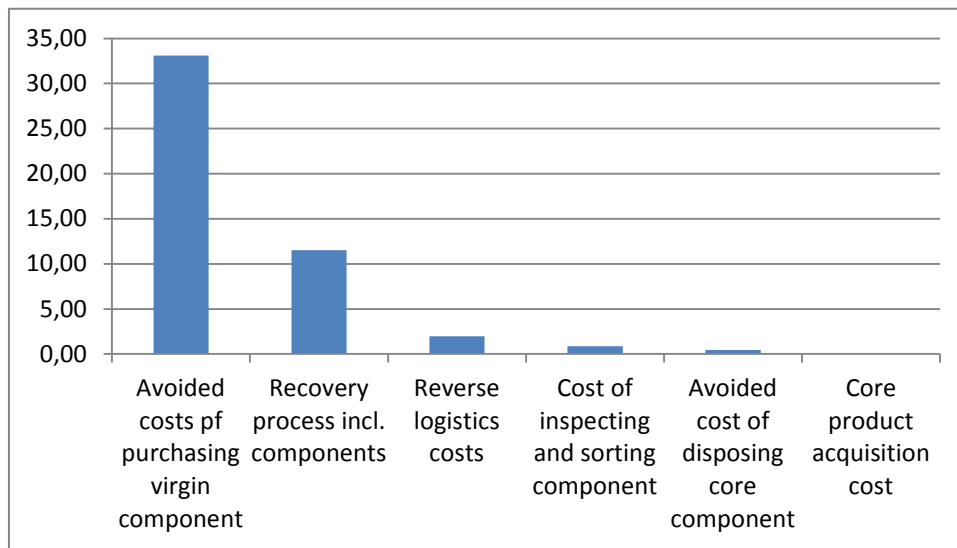


Figure 18 – Relative impact of factors for RSC-function no. 2

5.1.3 RSC-FUNCTION 3: REUSE OF PACKAGING MATERIALS FOR THE PURPOSE OF REPLACING THE PURCHASE OF VIRGIN PACKAGING MATERIALS

Figure 19 shows the avoided costs of purchasing virgin packaging materials and the reverse logistical costs of collecting and transporting packaging materials as the two only decisive factors. Internal recovery costs and the costs of disposing worn items are limited. The case firm's sales staff dismisses any effects on prices resulting from performing the service of taking back packaging materials, although take-back of packaging materials relieves customers of handling packaging materials in-house.

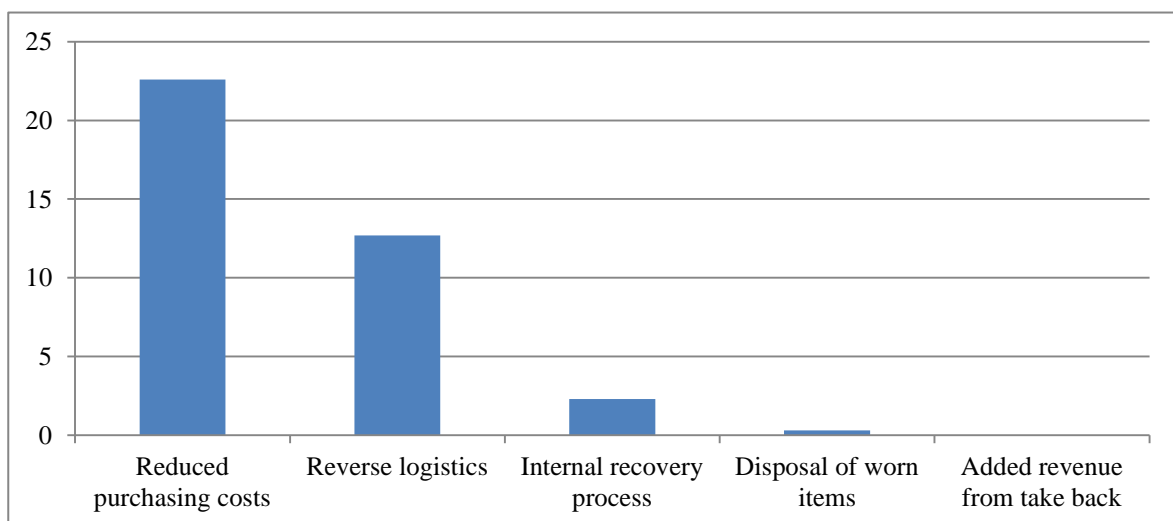


Figure 19 – Relative impact of factors for RSC-function no. 3

The study's perhaps most surprising result when looking across all three cases is that the decisive factors for the RSC's financial contribution are contextual to the RSC, rather than stemming from the inherent processes of the RSC itself. The reason for the surprise is the intense focus from the academic research community into RSC processes, in particular reverse logistics processes (Sasikuma and Kannan, 2008; Pokharel and Mutha, 2009). By contrast, this study shows that a number of high-impact factors are either nearly or completely unexplored in scholarly publications. For example, 1) the margins of service operations, 2) the probability-increase for up-selling additional products, and 3) the cannibalization of virgin product sales. While OM literature has examined cannibalization effects and willingness-to-pay for recovered products in a few publications, the impact of service operation margins and the probability increases are unexplored.

5.2 THE FACTORS DECISIVE FOR THE INDUSTRIAL UTILIZATION OF RSC-ENABLED REVENUE STREAMS

P-1 concerns the RSC-enabled revenue streams available to OEMs and the industrial utilization of these streams. The number and nature of the RSC-enabled revenue streams available to OEMs constitutes a part of the answer to the first of the thesis' two research questions about how the RSC can contribute to the financial performance of the firm, and are therefore already presented in section 4. The factors that explain the industrial utilization of revenue streams contribute to the second of the thesis' two research question and are therefore presented here in section 5.

P-1 analyses eight cases using *within-case* and *cross-case* analysis (Miles *et al.*, 2014; Yin, 2014). First, the study identifies revenue stream utilization *within* cases; second, the study identifies explanatory variables; third, the study analyzes the overall utilization pattern *across* cases; and fourth, the study discusses whether and how explanatory variables from the within-case analysis can explain the cross-case pattern. The fourth step in the sequence develops a set of propositions that link explanatory variables with the cross-case utilization pattern. Table 7 presents the set of propositions in the right-hand column.

Table 7 – Propositions (P-1)

	Reasoning linking proposition to case analysis	Propositions explaining pattern in revenue stream utilization
P1	The firm may risk to erode their brand value if customers experience low quality in IRF-recovered products	A high risk of brand value erosion caused by customers' experiencing low quality in IRF-recovered items influences utilization negatively
P2	A low reverse flow of core products makes the firm less likely to implement RSC-processes	A large reverse flow of core products influences utilization positively
P3	If customers place high value on recovered products and low (or no) value on core products, the resale revenue can supersede RSC-costs	A high value gap between core and recovered products influences utilization positively
P4	If items are highly customized, the market for core or recovered items is limited	A high degree of product and component customization influences utilization negatively
P5	If virgin product manufacturing costs are high compared to recovery, then recovery becomes feasible (assuming prices for recovered items supersede RSC-costs)	High virgin product manufacturing costs influences utilization positively
P6	If the firm has an accessible supply of core products, then the costs of product acquisition are lower	Accessibility of core products influences utilization positively
P7	If core products are large and heavy, then reverse logistics costs will decrease the likelihood of profitable recovery and resale	Large dimensions and heavy weight of core products influences utilization negatively
P8	If products' life-cycle is long, the firm has a longer window for reselling recovered products and components	A long product life-cycle influences utilization positively
P9	If customers value RSC-enabled services, the firm can achieve higher per-product revenue or win larger market shares	Customers placing high value on RSC-enabled services influences the utilization positively

Section 4 shows that revenue resulting from resale of core components or core-end-products to independent recovery firms (A1-2) and resale of recovered components to direct competitors and related manufacturers (B5) are un-utilized by all eight case firms in the study's dataset. The propositions in Table 7 suggest that these streams are unattractive to OEMs because of the risk of brand value erosion, components' high degree of customization, and large core product "physics". However, the propositions also define potential contexts within which the pursuit of these RSC-enabled revenue streams becomes worthwhile. To exemplify, no case firm utilizes resale of core components to original component suppliers (A4), but the propositions suggest that utilization is feasible under the following conditions: 1) the OEM has access to a large flow of core

products; 2) these products are low-weight with small dimensions; and 3) end-products have long product life-cycles (that ensure the supplier a market for recovered components).

6 DISCUSSION

This section discusses the thesis' findings and how these findings are positioned vis-à-vis the overall RSC literature stream.

6.1 WHETHER THE USE OF RSC-FUNCTIONS CORRELATE POSITIVELY WITH THE FIRM'S FINANCIAL PERFORMANCE

Although the thesis has dealt with nothing but the relationship between the RSC and the firm's financial performance, a perhaps central question remains unexplored in the thesis. That is the question of whether the firm's financial performance increases with the increasing use of RSC-functions. In effect, this is the classical theory-building question. The thesis has not answered this question directly, but does have results that point in the direction of a positive correlation. P-6 analysed three cases quantitatively to extract the set of factors decisive for the RSC's financial performance contribution. These three cases were not chosen for their positive RSC-impact on the firm's financial performance, but because they met a set of criteria that match the firms in the thesis domain limitation. All three cases show positive net contributions, which are even quite substantial in size. Three cases with positive correlations are not enough data points for statistical conclusions, but do indicate that the RSC *can* provide value for the firm. In addition to these three cases, P-5 gives a perhaps clearer indication of the correlation. P-5 examines the profit-potential in RSC-functions with a catalyst manufacturer. Because catalyst manufacturing is characterized by highly standardized and controlled manufacturing environments, one could argue that the catalyst industry constitutes an extreme case given the inherent uncertainties of the RSC (e.g. the quality of returned core products). The case still provides a positive net contribution from the RSC to the firm's bottom line.

The thesis is not the first paper to examine the net contribution of RSCs. But instead of studying the RSC's contribution to the firm's financial performance in many individual firms and industries, the thesis has looked for the factors that are decisive for the RSC's contribution. P-2 shows that many papers have investigated the impact of individual factors on the costs of operating a RSC (e.g. Bhattacharya and Kaur, 2015; and Canella *et al.*, 2016). However, this thesis is the first to examine the relative impact of factors to determine which factors are the decisive ones. Interestingly, the thesis has discovered a missing balance between the factors that receive scholarly attention and the factors with high impact on the RSC's contribution.

6.2 THE CONCEPT OF THE RSC-FUNCTION

The Introduction described the concept of the RSC-function and that one RSC can conduct more than one function for the firm simultaneously. In fact, all case firms examined in this thesis operate RSCs with several RSC-functions.

Within RSC-literature the majority of papers that address RSC-issues examine one particular RSC-function that recovers complete end-products for the purpose of resale to the firm's primary market. Figure 20 illustrates the function. This thesis conducted a preliminary literature review in 2013 about RSC-enabled revenue streams. The review shows that more than 70% of papers that concern RSC-revenue address this particular RSC-function. That the majority of papers addressing this particular RSC-function is so overwhelming, indicates that academia perceives this RSC-function as *the* RSC, rather than just one of many functions that the RSC can do for the firm.

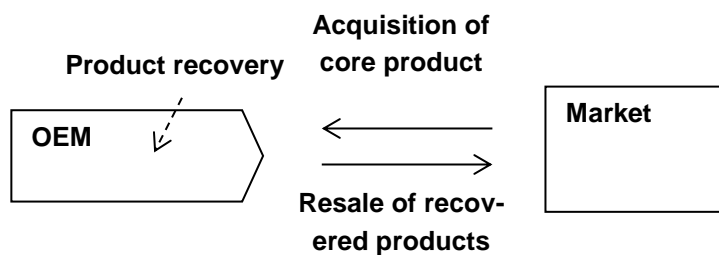


Figure 20 – Most researched RSC-function

The concept of the RSC-function implicates that 1) RSCs conduct functions for the firm, 2) several of these functions can co-exist in the firm's RSC simultaneously, and 3) each RSC-function contributes to the firm's financial performance individually. The RSC-function concept broadens managers' perception of what the RSC is and how the firm can use its RSC. For example, the study of RSC-enabled revenue streams reveal unexplored revenue streams. For example 1) resale of recovered components to direct competitors or related manufacturers and 2) resale of core materials to original suppliers. A key contribution in this study is broadening the possible buyer groups for items processed in the RSC.

Literature has published papers that implicitly address the RSC-function concept. Literature divides RSCs into high- and low-value RSC options and suggests research into RSCs with a cascading nature, where items unsuitable for recovery in a high-value function flow further upstream to low-value functions (Simpson, 2010, and Guide and Van Wassenhove, 2006). The concept of the RSC-function suggests that RSCs can entail both high- and low-value functions within the same RSC and that these functions can share costs of e.g. product acquisition and reverse logistics costs. Klausner and Hendrickson (2000) exam-

ine a RSC that remanufactures power tools and recycles materials. Although recycling is not within the scope of the thesis' focal firm, the study by Klausner and Hendrickson concludes that only one function is profitable in isolation, but both functions are profitable when costs are shared.

6.3 THE RSC'S RELATED CONCEPTS

The thesis contributes to the understanding of theoretical concepts related to the RSC as well as the RSC concept itself. The "closed-loop supply chain" (CLSC), "product recovery management" (PRM), and "reverse logistics" (RL) are examples of related concepts. The CLSC and PRM (Thierry et al, 1995; Guide and Van Wassenhove, 2009) pair the practical, physical RSC with the firm's purpose for operating it. The CLSC-concept advocates "maximizing value" over the entire life-cycle of a product as the purpose for operating the RSC, while PRM advocates "recovering value". For both the CLSC and PRM the nuts-and-bolts operating system that performs the recovery cycles that maximize or recover value are the five processes that constitute the RSC (described in the thesis introduction). Hence, a contribution to the understanding of the RSC implicates a contribution to the understanding of the CLSC and PRM concepts as well. Concerning RL, which the thesis has described as an early account of the RSC concept in the introduction, the thesis applies a narrow definition of RL as reverse transportation and core product inventory management. However, several academics (including several of the references within the thesis' literature review) use a broader RL-definition, which roughly equates this thesis' RSC-definition. Therefore, the thesis essentially makes the same theoretical contribution to the broader RL-concept as to the RSC concept.

6.4 DECISIVE FACTORS: PRODUCT LIFE-CYCLE LONGEVITY, PRODUCT DURABILITY, AND TECHNOLOGY PLATFORM DEVELOPMENT SPEED

P-1 developed the proposition that the life-cycle longevity impacts the utilization of revenue streams that stem from resale of recovered products. The paper argues that long product life-cycles (PLC) widen the time interval during which recovered products are in demand, and, therefore, long product life-cycles impact the utilization of the revenue stream. If the stream is profitable for the firm to utilize then the RSC contributes positively to the firm's financial performance.

P-1's data suggests a causal relationship between PLC-length and the degree of utilization of the RSC-function "take-back, recover, and resell end-products". However, one could argue that the factor that causes a higher degree of utiliza-

tion of the RSC-function is not the PLC-length in alone, but instead the relationship between PLC-length and average length of a product's use. For the purpose of this discussion PLC-length is defined as the time interval between the product-introduction and last product sale (in virgin condition to primary market customers) and the average use-length is defined as the average time interval between initial product purchase and the time when the product reaches end-of-life condition. If the PLC-length is much longer than the use-length, then the firm will have access to core products to recover and resell before demand for the product declines. If, on the other hand, the average use-length is longer than or equal to the product's PLC-length, then core products will not be available before the demand window closes. These products may still be in demand in secondary markets, but primary market customers will have moved on to newer versions of the product. P-1 and P-4 delineates the (many) financially contributing disposition strategies available for core products that return after the last virgin product sale. In addition, several scholars examine the process of remanufacturing that can upgrade older versions of products to include functionality of newer product versions (e.g Hazen *et al.*, 2012)

One could argue that the technology platform speed impacts the product's PLC-length. Tibben-Lembke (2002) as well as Gobbi (2011) mention the pace of technology evolution as a factor. The impact is worth examining in future research. This thesis argues that the technology platform development speed impacts both the PLC-length and the average use-length. A faster pace reduces the PLC-length and the use-length, albeit in different magnitudes. The PLC-length is squeezed by an incoming new version of the product, while customers are more inclined to exchange their product when the new version has arrived.

7 CONCLUSIONS

The first of the thesis' two research questions concerns how the RSC can contribute to the firm's financial performance. The thesis has divided this question into two subquestions concerning how the RSC can increase the firm's revenue and how the RSC can reduce the firm's costs. The domain of the thesis is limited OEMs.

The thesis shows that the RSC makes ten revenue streams available for OEMs through take-back and resale of the firm's core products, components, or materials, all in either as-is or recovered condition. In addition to these ten revenue streams, the RSC enables higher virgin product revenue by increasing the firm's ability to compete in their primary markets through either Differentiation or Cost Leadership strategies. The RSC can increase the firm's ability to compete through the Differentiation strategy by, for example, including in the firm's total product offering services such as liberal return policies, fast repair, or immediate replacement of defective products. Furthermore, the RSC can increase the firm's ability to compete on the Cost Leadership strategy by extending the firm's product portfolio with lower-priced recovered products or by offering remanufacturing of a customer's core product as a lower priced alternative to the purchase of a new virgin product. In addition to enabling increased revenue, the RSC provides a number of cost reduction opportunities, which contribute to the firm's financial performance regardless of competitive strategy. The thesis has identifies three types of cost reduction: replacing purchasing of virgin materials, virgin component fabrication, and virgin product assembly, with recovered products and components. For example, the firm can exchange virgin components with recovered components when servicing their installed base or use recovered products when customers return defective products still within warranty.

The second of thesis' two research questions concerns the factors that are decisive for the size of the RSC's contribution to the firm's financial performance and whether the RSC can make a contribution at all. The thesis examines decisive factors for three specific RSC-functions, and, in addition, examines the factors decisive for the industrial utilization of the revenue streams described in the previous paragraph. The three specific RSC-functions are: recovery and resale of recovered products, recovery and reuse of components, and take-back and direct reuse of packaging materials. For recovery and resale of recovered products, the decisive factors are 1) customers' willingness-to-pay for recovered products, which is reflected in the sales price; 2) the amount and margins on the service that accompanies the recovered product; 3) the size of the probability-increase for selling additional products to the customer of the recovered product; 4) the probability of cannibalizing the sale of an equivalent virgin product;

and 5) the cost of acquiring the core product. Interestingly, the costs of operating the RSC, e.g. the costs of reverse logistics, which is well-researched in literature, has virtually no impact on the RSC's contribution to the firm's financial performance. For recovery of and reuse of components the decisive factors are the size of the avoided cost of purchasing an equivalent virgin product, and the costs of those subcomponents needed to recover the core product, while the decisive factors for takeback and direct reuse of packaging materials are the avoided costs of virgin packaging materials and the costs of reverse logistics that physically move core packaging materials from customer locations to the firm's inspection and sorting site. For the utilization of RSC-enabled revenue streams, findings shows that the decisive factors among others are 1) core product accessibility, 2) the size of the value gap between core and recovered items, 3) the degree of product and component customization, and 4) the product life-cycle longevity.

8 LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The thesis has used a methodology that combines case research with the study of literature and conceptual modeling. The limitations inherent the thesis' methodology opens up several opportunities to further examine the relationship between the RSC and the firm's financial performance. The thesis specifically suggests survey research that 1) relates the extent of RSC-use with the firm's financial performance, and 2) relates the factors (that this study argues are decisive for the RSC's contribution) to the size of the RSC's contribution. P-1 has developed a set of testable propositions that could feed into survey research. For example, examining whether firms that sell products with long product life-cycles operate RSCs that make larger contributions than RSCs of firms with short life-cycle products. Such studies could also identify additional variables that this thesis has not found.

In addition to the future research options that follow this thesis directly, the thesis suggests research about managerial issues related to the utilization of RSC-enabled revenue streams. For example competition issues relevant for firms choosing to resell core products to independent recovery firms (IRFs), the risks inherent in selling recovered products (e.g. cannibalization effects), and contractual design issues related to the resale of core items to IRFs. Furthermore, research could conduct research into the prevalence of the pursuit of the RSC's contribution to the firm's financial performance, and to which degree RSCs make positive contributions at all. Finally, future research could study the impact of service margins and service needs on the RSC's financial performance contribution, and impact of customers' switching costs on the the upsale-probability-increase stemming from selling a recovered product to a new customer.

9 CONTRIBUTION TO THEORY

Overall, the thesis supports the effort to recast the role of the RSC from "the unwanted stepchild" to a driver of value. The thesis differs from the traditional RSC cost reduction literature by adopting the RSC-literature's business perspective described by Guide and Van Wassenhove in 2000s (e.g. Guide and Van Wassenhove, 2006). The perspective views the RSC as a value creator rather than a costly nuisance for the firm. While P-1 and P-4 delineate how the RSC can increase the firm's revenue and lower the firm's costs, P-3 argues that the RSC can have a strategic role in the firm's competitive strategy. Specifically, the thesis contributes to the academic challenge of establishing the RSC as an independent profit-centre in the organization (Huscroft *et al.*, 2013).

In addition to contributing to the business perspective literature stream, the thesis extends the literature streams about disposition strategy choice, remarketing, and the prerequisites for the RSC's financial success. For example, the thesis extends the work of Skinner *et al.* (2008) and Hazen *et al.* (2012) that examine disposition strategy choice. The thesis extends their work by broadening the possible disposition strategies by including various versions of resale as decision outcomes. The thesis contributes to remarketing literature (e.g. Atasu *et al.*, 2010) by providing a comprehensive set of opportunities for remarketing. Concerning the prerequisites for the RSC's financial success Guide and Van Wassenhove (2009) argue for the existence of three prerequisites: Having access to enough core products, being able to recover these at a reasonable cost, and developing customer markets for recovered products. These three prerequisites address the processes inherent in RSC itself. The thesis supports these three prerequisites, but also extends the set by including issues contextual to the RSC. For example, whether the life-cycle of virgin products is long and how customers value services enabled by the RSC when making purchase decisions.

The introduction discussed the nature of a theoretical contribution in the OM and general management field. According to Wacker (1998) a theoretical contribution within the OM field relates two constructs to one another within a limited domain. In addition, a theory can predict the consequences of changes in the independent construct for the dependent construct. This thesis relates the RSC to the financial performance of the firm and limits the domain of the thesis to OEMs only. The domain limitation defines the "where/when" of the thesis, the constructs the "what", the answers to the two research questions the "how" and the "why" of the thesis. Concerning the ability to predict the change in the firm's financial performance based on changes in the firm's use of their RSC, the thesis provides no simple answer, e.g. in form of "the more the firm uses its RSC,

the better the firm's financial performance". The thesis has found that the impact of the RSC on the firm's financial performance is heavily influenced by a set of factors (e.g. customer's willingness-to-pay for recovered products and the cannibalization effect that reselling a recovered product has on the sale of virgin products). The thesis offers OEMs an ability to predict the financial performance contribution of their RSC by analyzing these factors. The thesis has examined the relative impact of a vast number of factors to identify what the thesis labels the decisive factors the RSC's financial performance contribution.

The perhaps single most important contribution to the existing RSC-literature is to redirect the academia' focus from examining the processes of the RSC, reverse logistics in particular, towards a focus on the factors that have a larger impact on the RSC's contribution to the firm's financial performance. Instead of examining e.g. vehicle routing, inventory management, network design etc., the thesis suggests a path towards a better understanding of the RSC's impact on 1) the forward supply chain's ability to sell virgin products and services and 2) the potentially avoided cost of purchasing virgin components and packaging materials.

10 CONTRIBUTION TO PRACTICE

The results of the thesis apply to firms within the thesis' domain limitation, which the introduction defines as OEMs that produce and sell durable and technically recoverable products. The set of practitioners that can use the results of the thesis include first and foremost logistics and supply chain managers, operations managers, and sales and marketing roles, because these roles are directly connected to the RSC-processes in the firm. However, P-5 shows that the implementation of RSC-functions may require staff from tax departments, legal departments, product management, and suppliers as well.

For practitioners the thesis constitutes a framework for deciding which (if any) RSC-functions the firm can implement and operate profitably. The framework consists of two distinct parts: 1) a set of theoretically available RSC-functions and 2) a set of decision variables. The set of theoretically available RSC-functions stem from the answer to thesis' first research question concerning how the RSC can contribute to the financial performance of the firm, and the set of decision variables stem from the thesis' second research question concerning which factors are decisive for the size of RSC's financial performance contribution.

P-5 delineates a procedure for how practitioners can apply the framework. The paper details the procedure for how a catalyst manufacturer has used the framework. The firm applied a two-step procedure. In the first step a set of selected roles from the firm conducted a qualitative screening of 20 theoretically RSC-functions. In the second step the firm conducted a detailed analyses (including business cases) of the RSC-functions that were selected in the screening. The business case analyses showed three profitable RSC-functions, of which the firm chose to implement one (in the short term).

The thesis shows how the RSC can create value for manufacturers of all sizes within a wide array of industries, ranging from manufacturers of heavy industry equipment to manufacturers of hearing aids. While some industries may benefit from taking back products for the purpose of disassembly and resale of materials, other industries can benefit from replacing virgin product assembly with recovery of core products. The thesis documents the breath in the value creation of the RSC.

10.1 WIDER DISSEMINATION AND FUTURE USE OF THE THESIS' RESULTS

The Danish Industry Foundation (Industriens Fond) has awarded DTU a grant of approximately 5 million DKK for the purpose of developing and disseminating a set of tools that enable small and medium-sized enterprises to increase the sustainability of their operations. On the basis of this PhD project the author of this thesis will develop an operational tool for assessing the viability of RSC operations for medium-sized manufacturers. The tool will be disseminated through a series of practitioner oriented conferences and work-shops held during 2017 and 2018.

In October 2016 the Danish Ministry of Environment and Food (Miljø- og Fødevareministeriet) and the Ministry of Business and Growth (Erhvervs- og Vækstministeriet) have established an advisory board to the Danish government about the implementation of circular economy. The advisory board's task is to develop a vision and set of objectives for the implementation of circular economy in Denmark. For manufacturers the circular economy is largely constituted by operating RSCs. Therefore, results of this PhD thesis are submitted to the board together with a set of specific suggestions for the board to consider. In addition, the author of the thesis has been in a dialogue with a board member working with recommendations to the government concerning circular economy for manufacturers

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12 PAPERS

The following pages of the thesis present the nine papers that the previous summary has described. Prior to each paper, the thesis describes each papers title, authors, outlet (conference or journal), and status (e.g. submitted, accepted, or published). The sequence follows Table 1 in the introduction of the thesis.